विद्या प्रसारक मंडळ, ठाणे

पुस्तकाचे नाव	:	श्रीभास्कराचार्यविरचित : लघुभास्करीयम
संपादक	:	शुक्ला, कृपाशंकर
प्रकाशक	:	लखनऊ : विश्वविद्यालय गणित व ज्योतिष विभाग
प्रकाशन वर्ष	:	१९६३
पृष्ठे	:	२११ पृष्ठे

गणपुस्तक

विद्या प्रसारक मंडळाच्या

“ग्रंथालय” प्रकल्पांतर्गत निर्मिती

गणपुस्तक निर्मिती वर्ष : २०१३

गणपुस्तक क्रमांक : ००७

BHĀSKARA I AND HIS WORKS

PART III

LAGHU-BHĀSKARĪYA

Edited and Translated into English

With Explanatory and Critical Notes and Comments, etc.

by

KRIPA SHANKAR SHUKLA, M. A., D. Litt.

Reader in Mathematics, Lucknow University

Published by

Department of Mathematics and Astronomy

Lucknow University

1963

श्रीभास्कराचार्यविरचितम्

लघुभास्करीयम्

लखनऊ-विश्वविद्यालयस्य गणिताध्यापकेन एम० ए०, डी० लिट्० इत्युपाधिधारिणा

श्री कृपाशंकर शुक्लेन

आङ्ग्लानुवाद – व्याख्या–टिप्पण्यादिभिः सहितं

सम्पादितम्

लखनऊ विश्वविद्यालयस्य गणित-ज्योतिष-विभागेन

प्रकाशितम्

सं० २०२० वि०

First Edition 1963

Price: Rs. 60.00
$ 10.00

Printed by
. Chandra, Star Press, Lucknow
(Phone 24768)

PREFACE

The object of the "Hindu Astronomical and Mathematical Texts Series" is to bring out authoritative and critical editions of important unpublished works dealing with ancient Hindu astronomy and mathematics. The present edition of Bhāskara I's *Laghu-Bhāskarīya* is No. 4 of this series.

The idea of bringing out the above series is due to Dr. A. N. Singh, late Professor of Mathematics, Lucknow University, who organised a scheme of research in the history of Hindu mathematics and astronomy in the Department of Mathematics, Lucknow University, with the object of collecting, studying, and editing important works on Hindu mathematics and astronomy. Under his able supervision remarkable progress was made in this direction and a number of manuscripts were acquired, studied and edited. The work is being continued since his death in 1954 by our colleague, Dr. Kripa Shankar Shukla, Reader in Mathematics, Lucknow University, who has already been actively engaged in this work since 1941.

The scheme of research in the history of Hindu mathematics and astronomy referred to above has been financed by the Government of Uttar Pradesh, through the help of Dr. Sampurnanand, its then Education Minister, for which we offer our sincere thanks to them. We are particularly grateful to Dr. Sampurnanand for taking keen and abiding interest in the progress of our research and encouraging us from time to time.

The present publication has been made out of a grant of Rs. 3,000/- kindly sanctioned by the Government of Uttar Pradesh, for which we once again express our sincere thanks to them. Our thanks are especially due to Acharya Jugal Kishore, our present Minister of Education, for sanctioning the above grant.

R. Ballabh

CONTENTS

Page

Introduction i

Sanskrit Text

प्रथमोऽध्यायः १

द्वितीयोऽध्यायः ५

तृतीयोऽध्यायः १०

चतुर्थोऽध्यायः १४

पञ्चमोऽध्यायः १८

षष्ठोऽध्यायः २०

सप्तमोऽध्यायः २३

अष्टमोऽध्यायः २५

शब्दानुक्रमणिका २८

छन्दानुक्रमणिका ३८

English Translation

Chapter I. MEAN LONGITUDES OF THE PLANETS 1

Homage to the Sun vs. 1—Homage to Āryabhaṭa I 2—Appreciation of Āryabhaṭa I and his work 3—Calculation of the *Ahargaṇa* 4-8—Revolution-numbers of planets 9-14—Calculation of mean longitudes of planets 15-17—Positions of apogees of planets 18—Epicycles of planets 19-22—Hindu prime meridian 23—A rule for the distance from the prime meridian and its criticism 24-27—Criticism of another rule 28—Longitude in time 29—Criterion for knowing whether the local place is to the east or to the west of the prime meridian 30—The longitude correction and its application 31—Another rule for distance from the prime meridian 32—Alternative rule for the longitude correction 33- Justification of the longitude correction 34—Demonstration of the same 35—Consequences of improper application of the longitude correction 36—Comparison of corrections for longitude and parallax (*lambana*) 37.

Page

Chapter II. TRUE LONGITUDES OF THE PLANETS 16

Sun's mean anomaly and its Rsine 1-3(i)—Sun's equation of the centre (*bhujāphala*) 3(ii)-4(i)—Sun's correction for the equation of time due to the eccentricity of the ecliptic 4(ii)-5—True distances of the Sun and Moon 6-7—True daily motion of the Sun and Moon, by various methods 8-15—Sun's declination, earthsine, and ascensional difference 16-18—Correction for the Sun's ascensional difference 19-20—Lengths of day and night 21—Corrections for the Moon 22-24—*Nakṣatra* 25-26(i)—*Tithi* 26(ii)-27—*Karaṇa* 28—The three kinds of *Vyatīpāta* 29—Corrections for the planets, Mars, etc. 30-39—Criterion for knowing whether a planet is stationary 40—Retrograde and direct motions 41.

Chapter III. DIRECTION, PLACE, AND TIME FROM SHADOW 41

Determination of directions 1—Latitude and colatitude of the local place 2-3—Ascensional differences of the signs 4—Times of rising of the signs at the equator 5—Times of rising of the signs at the local place 6—Sun's zenith distance and the shadow of the gnomon for the given time 7-11—Time corresponding to the given shadow in the forenoon or afternoon 12-15—Sun's *śaṅkvagra* 16—Longitude of the rising point of the ecliptic for the given time and *vice versa* 17-20—Sun's *agrā* 21—Sun's altitude and longitude when the Sun is on the prime vertical 22-25—Reduction of Rsine to the corresponding arc 26—Midday shadow from the Sun's declination and the latitude of the place 27-28—Sun's declination and longitude, and the latitude of the local place from the midday shadow of the gnomon 29-35.

Chapter IV. THE LUNAR ECLIPSE 58

Longitudes of the Sun and Moon when they are in opposition or conjunction in longitude 1—Distances of the Sun and Moon 2-3—Diameters of the Sun, Moon and Earth 4-5—Length of the Earth's shadow 6—Diameter of the Earth's shadow where the Moon crosses it 7—Moon's latitude 8—Measure of the Moon's diameter unobscured by the shadow 9—*Sparśa* and *mokṣa sthityardhas* (*i.e.*, durations of eclipse before and

Page

after the time of opposition) 10-12—Times of first and last contacts 13—*Sparśa* and *mokṣa vimardārdhas* (*i.e.*, durations of totality before and after the time of opposition) 14—Projection of an eclipse: *Akṣavalana* 15-16—*Ayanavalana* 17—Resultant *valana* 18—Corrected *valana* 19-20—*Valana* for the middle of an eclipse 21—Conversion of minutes of arc into *aṅgulas* 22—Construction of the figure of an eclipse 23-30—Construction of the phase of an eclipse for the given time 31-32.

Chapter V. THE SOLAR ECLIPSE 74

Longitude of the meridian-ecliptic point 2-4(i)—*Dṛkkṣepa* for the time of geocentric conjunction in longitude of the Sun and Moon 1, 4(ii)-7(i)—*Dṛggatijyā* for the same time 7(ii)-8(i)—*Lambana* for the time of apparent conjunction of the Sun and Moon 8-10—*Nati* for the same time 11—Moon's true latitude for the same time 12—*Sparśa* and *mokṣa sthityardhas* (*i.e.*, durations of eclipse before and after the time of apparent conjunction) 13-14—Condition for the impossibility of a solar eclipse 15.

Chapter VI. VISIBILITY, PHASES, AND RISING AND SETTING OF THE MOON 83

Visibility corrections 1-4—Minimum distance of the Moon from the Sun, in degrees of time, at which she becomes visible 5—Measures of illuminated and unilluminated parts of the Moon 6-7—Elevation of the lunar horns: Moon's *śaṅkvagra* for sunset 8—Moon's true declination and *agrā* 9-10—*Bāhu* (*i.e.*, base of the elevation triangle) 11-12(i)—Construction of the figure exhibiting the elevation of the lunar horns 12(ii)-18—Duration of Moon's visibility in the light half of the month 19—Time of Moonrise on the full moon day 20-21—Shadow of the gnomon due to the Moon 22—Time of moonrise in the dark half of the month 23-25.

Chapter VII. VISIBILITY AND CONJUNCTION OF THE PLANETS 92

Minimum distances of the planets from the Sun, in degrees of time, at which they become visible 1-2—Degrees of time between the Sun and a planet 3—Time and common longitude of two planets when they are in conjunction in

Page

longitude 4-5—Latitudes of those planets for that time 6-9(i)—Distance between two planets when they are in conjunction in longitude 9-10.

CHAPTER VIII. CONJUNCTION OF A PLANET AND A STAR 95

Longitudes of the junction-stars of the twenty-seven *nakṣatras* 1-4—Conjunction of a planet with a star 5—Celestial latitudes of the junction-stars of the twenty-seven *nakṣatras* 6-9—Definition of absolute conjunction of the Moon with a star 10—Celestial latitudes of the Moon when she occults some of the prominent stars of the zodiac 11-16—Two astronomical problems on indeterminate equations 17-18—Object, scope, and authorship of the book 19.

Appendices

1. Theory of the pulveriser as applied to problems in astronomy by Bhaṭṭa Govinda 103
2. Passages from the *Laghu-Bhāskarīya* quoted or adopted in later works 115

GLOSSARY 120

TRANSLITERATION

Vowels

Short :	अ	इ	उ	ऋ			
	a	*i*	*u*	*ṛ*			
Long :	आ	ई	ऊ	ए	ऐ	ओ	औ
	ā	*ī*	*ū*	*e*	*ai*	*o*	*au*
Anusvāra :	ं	=	*ṁ*				
Visarga :	ः	=	*ḥ*				
Non-aspirant:	ऽ	=	’				

Consonants

Classified:	क्	ख्	ग्	घ्	ङ्			
	k	*kh*	*g*	*gh*	*ṅ*			
	च्	छ्	ज्	झ्	ञ्			
	c	*ch*	*j*	*jh*	*ñ*			
	ट्	ठ्	ड्	ढ्	ण्			
	ṭ	*ṭh*	*ḍ*	*ḍh*	*ṇ*			
	त्	थ्	द्	ध्	न्			
	t	*th*	*d*	*dh*	*n*			
	प्	फ्	ब्	भ्	म्			
	p	*ph*	*b*	*bh*	*m*			
Unclassified:	य्	र्	ल्	व्	श्	ष्	स्	ह्
	y	*r*	*l*	*v*	*ś*	*ṣ*	*s*	*h*
Compound:	क्ष्	त्र्	ज्ञ्					
	kṣ	*tr*	*jñ*					

LIST OF ABBREVIATIONS

Ā	*Āryabhaṭīya*
BJ	*Bṛhaj-jātaka*
BrSpSi	*Brāhma-sphuṭa-siddhānta*
GL	*Graha-lāghava*
KK	*Khaṇḍa-khādyaka*
KKau	*Karaṇa-kaustubha*
KKu	*Karaṇa-kutūhala*
KPr	*Karaṇa-prakāśa*
LBh	*Laghu-Bhāskarīya*
LMā	*Laghu-mānasa*
MBh	*Mahā-Bhāskarīya*
MSi	*Mahā-siddhānta*
MuCi	*Muhūrta-cintāmaṇi*
PiSi	*Pitāmaha-siddhānta* (of *Viṣṇu-dharmottara-purāṇa*)
SK	*Sarvānanda-karaṇa*
ŚiDVṛ	*Śiṣya-dhī-vṛddhida*
SiSā	*Siddhānta-sārvabhauma*
SiŚe	*Siddhānta-śekhara*
SiŚi	*Siddhānta-śiromaṇi*
SiTV	*Siddhānta-tatva-viveka*
SūSi	*Sūrya-siddhānta*
TS	*Tantra-saṅgraha*
VSi	*Vaṭeśvara-siddhānta*
ViMā	*Vidyā-Mādhavīya*
VVSi	*Vṛddha-Vaśiṣṭha-siddhānta*

INTRODUCTION

This Part contains a critically edited text of the *Laghu-Bhāskarīya* ("the smaller work of Bhāskara I") and its English translation with notes and comments where necessary.

Sanskrit Text. In editing the text I have made use of the following four manuscripts in the collection of the late Dr. A. N. Singh :

MS. A—Containing the text only ;

MS. B—Containing the text together with the commentary of Śaṅkaranārāyaṇa (869 A. D.);

MS. C—Containing the text together with the commentary of Udayadivākara (1073 A. D.) ;

MS. D—Containing the text together with the commentary of Parameśvara (1408 A.D.).

The manuscripts consulted by me are generally in good condition but at places there are imperfections and omissions. In none of them are the verses numbered. MSS. A, B, and C are complete whereas MS. D breaks off at the end of the seventh chapter. B. D. Apte acquired a complete copy of MS. D which he has published in the Ānandāśrama Sanskrit Series. I have called his edition P.

The following is a chapterwise analysis of the extents of the manuscripts consulted by me :

Chapter	Number of verses					
	MS. A	MS. B	MS. C	MS. D	P	Common to all
I	38	37	37	37	37	37
II	41	40	41	41	41	40
III	35	35	35	35	35	35
IV	32	32	32	32	32	32
V	15	15	15	15	15	15
VI	25	25	25	25	25	25
VII	10	10	10	12	12	10
VIII	19	19	19	19	19	19

Total number of verses common to all manuscripts = 213

The above table shows that

(1) MS. A contains an additional verse in Chapter I,

(2) MSS. A, C, D and P contain an additional verse in Chapter II, and

(3) MS. D and P contain two additional verses in Chapter VII.

Of these additional verses, the one belonging to Chapter II possibly belonged to the original text of the *Laghu-Bhāskarīya*. The other additional verses are interpolatory as the following discussion will show.

Discussion of Additional Verses

(1) Additional Verse in Chapter I. This verse occurs in MS A between verses 17 and 18, and runs as follows:—

वाग्भावोनाच्छकाब्दाद् धनशतलयहान्मन्दवैलक्ष्यरागैः
प्राप्ताभिर्लिप्तिकाभिर्विरहिततनवश्चन्द्रतत्तुंगपाताः ।
शोभानीरूढसंविद्गणकनरहतान्मागराप्ताः कुजाद्याः
संयुक्ता ज्ञारसौराः सुरगुरुभृगुजौ वर्जितौ भानुवर्ज्यम् ॥[1]

[Translation. The mean longitudes of the Moon, its apogee and ascending node should be (respectively) diminished by the minutes of arc which are obtained by diminishing the (elapsed) years of the Śaka era by 444, (then severally) multiplying (that difference) by 9, 65, and 13 and dividing them by 85, 134, and 32 (respectively). (Severally) multiplying (the same difference) by 45, 420, 47, 153, and 20 (respectively) and dividing (all of them) by 235 are obtained (the corrections in minutes of arc) for Mars, etc. (The corrections) for (the *śīghrocca* of) Mercury, Mars and Saturn should be added (to their mean longitudes); (those) for Jupiter and (the *śīghrocca* of) Venus should be subtracted (from their mean longitudes). The Sun is to be excluded (from this correction).]

This verse states the so-called *śakābda* correction, which, stated in the tabular form, is a follows:

---

[1] *vāgbhāvonācchakābdād dhanaśatalayahānmandavailakṣyarāgaiḥ*
prāptābhirliptikābhirvirahitatanavaścandratattuṅgapātāḥ ।
śobhānīrūḍhasaṃvidgaṇakanarahatānmāgarāptāḥ kujādyāḥ
saṃyuktā jñārasaurāḥ suragurubhṛgujau varjitau bhānuvarjyam ॥

Śakābda Correction for the Planets

Planet	Correction per annum
Sun	Nil
Moon	−9/85 minutes or −6″21‴
Moon's apogee	−65/134 minutes or −29″6‴
Moon's ascending node	−13/32 minutes or −24″22‴
Mars	+45/235 minutes or +11″29‴
Śīghrocca of Mercury	+420/235 minutes or +1′47″14‴
Jupiter	−47/235 minutes or −12″
Śīghrocca of Venus	−153/235 minutes or −39″4‴
Saturn	+20/235 minutes or +5″6‴

The above verse has already been proved to be interpolatory and not belonging to the original.[1] The reasons for that conclusion may be summarised here as follows :

(i) The correction stated in the above verse does not occur in the author's bigger work, the *Mahā-Bhāskarīya*, nor in his commentary on the *Āryabhaṭīya*.

(ii) The system of numeral notation used for forming number-chronograms in the above verse is *alphabetic (kaṭapayādi* system) whereas at other places in the *Laghu-Bhāskarīya* the author has used the word-numeral system.[2] In the other works of Bhāskara I, too, the latter system is used.

(iii) The language and style of this verse are not in conformity with the rest of the *Laghu-Bhāskarīya*.

[1] See Part I, Chapter II, 2·31.

[2] For the alphabetic and word-numeral systems of notation, the reader is referred to B. Datta and A. N. Singh, *History of Hindu Mathematics*, Part I, pp. 53 f.

(2) Additional Verse in Chapter II. The verse in question is

तिथ्यर्धहारलब्धानि करणानि बवादितः ।
विरूपाणि सिते पक्षे सरूपाण्यसिते विदुः ॥[1]

It occurs in MSS. A, C, D, and P and also in the *Mahā-Bhāskarīya*. In MS. B, too, it is found to occur ; but from the opening remarks of the commentator Śaṅkaranārāyaṇa it appears that he does not take it as forming part of the *Laghu-Bhāskarīya*. He writes :

"How is the *karaṇa* to be known ? This very *Ācārya* (*i.e.*, Bhāskara I) has stated (the method for determining) it in the *Bṛhat-karmanibandha* (*i e.*, the *Mahā-Bhāskarīya*). How ?

तिथ्यर्धहारलब्धानि करणानि बवादितः ।
विरूपाणि सिते पक्षे सरूपाण्यसिते विदुः ॥"[1]

The above verse may not have occurred in the *Laghu-Bhāskarīya* as Śaṅkaranārāyaṇa seems to believe, but as the verse is a composition of Bhāskara I and occurs in most of the manuscripts of the *Laghu-Bhāskarīya* and is relevant to the context, I have included it in the edited text. In my opinion the text would be incomplete without this verse. For, when the text gives rules for the *tithi*, *nakṣatra* and *vyatīpāta*, there is no reason why there should be no rule for the *karaṇa* which is an equally important element of the Hindu Calendar (Pañcāṅga).

(3) Additional Verses in Chapter VII. The following two verses are found to occur in MS. D in the seventh chapter between verses 9 and 10 of our edited text. In P they are included in the text and are numbered as 10 and 11.

अत्यष्टिविश्वरुद्राङ्कतिथ्याप्ता बाणसागराः ।
बिम्बानि भूसुताद्व्यासशीघ्रकर्णान्तरैः पुनः ॥[2]

---

[1] *tithyardhahāralabdhāni karaṇāni bavāditaḥ ।*
virūpāṇi site pakṣe sarūpāṇyasite viduḥ ॥

[2] *atyaṣṭiviśvarudrāṅkatithyāptā bāṇasāgarāḥ ।*
bimbāni bhūsutādvyāsaśīghrakarṇāntaraiḥ punaḥ ॥

हत्वा पृथक्शीघ्रकर्णव्यासयोगेन भाजितम् ।
कर्णे हीनेऽधिके स्वर्णं कुर्याद् बिम्बे स्फुटं भवेत् ॥[1]

[Translation. 45 severally divided by 17, 13, 11, 9, and 15 are the mean diameters (in minutes of arc) of the planets beginning with Mars (*i.e.*, of Mars, Mercury, Jupiter, Venus, and Saturn). Each diameter should be multiplied by the difference between the *śīghra-karṇa* and the radius[2] and then divided by the sum of the *śīghra-karṇa* and the radius;[2] and whatever is obtained should be added to or subtracted from the mean diameter, according as the *śīghra-karṇa* is less or greater (than the radius). Thus are obtained the true diameters (in minutes of arc).]

These two verses do not belong to the text because their contents are not in conformity with the teachings of Bhāskara I. The first of the two verses gives the mean diameters of the planets which are different from those given in the *Mahā-Bhāskarīya*[3] both in absolute and relative magnitudes as is clear from the following table :

Mean Diameters of the Planets

Planet	Mean diameters in minutes of arc	
	Mahā-Bhāskarīya	The first verse under consideration
Mars	32/25=1·28	45/17=2 64
Mercury	32/15=2·13	45/13=3·46
Jupiter	32/10=3·2	45/11=4·09
Venus	32/5=6·4	45/9=5
Saturn	32/30=1·06	45/15=3

[1] *hatvā pṛthakśīghrakarṇavyāsayogena bhājitam ।*
karṇe hīne'dhike svarṇaṁ kuryād bimbe sphuṭaṁ bhavet ॥

[2] The word *vyāsa* here means "radius".

[3] vi. 56.

The second verse gives the following formula for the true diameter of a planet:

$$\text{True diameter} = \text{mean diameter} - \frac{\text{mean diameter} \times (\text{śīghra-karṇa} - \text{radius})}{\text{śīghra-karṇa} + \text{radius}}$$

$$= \frac{\text{mean diameter} \times \text{radius}}{\frac{1}{2}(\text{śīghra-karṇa} + \text{radius})}.$$

The corresponding formula given by Bhāskara I in the *Mahā-Bhāskarīya* is[1]

$$\text{true diameter} = \frac{\text{mean diameter} \times \text{radius}}{(\text{śīghra-karṇa} \times \text{manda-karṇa})/\text{radius}}.$$

The two formulae are fundamentally different, because the former is based on the assumption that the true distance of a planet is equal to[2]

$$\tfrac{1}{2}(\text{śīghra-karṇa} + \text{radius}),$$

and the latter is based on the assumption that the distance of a planet is equal to

$$(\text{śīghra-karṇa} \times \text{manda-karṇa})/\text{radius}.$$

The verses in question occur in MS. D, which contains the commentary of Parameśvara, but have not been commented upon by the commentator. Evidently they are quotations cited by the commentator.

Discarding the additional verses of Chapters I and VII and counting that of Chapter II, the text edited by me comprises 214 verses. The size of the *Laghu-Bhāskarīya* is thus approximately half that of the *Mahā-Bhāskarīya* which contains 403½ verses.

[1] Cf. *MBh*, vi. 58(ii).

[2] This is in agreement with what Burgess interprets to be the meaning of *SūSi*, vii. 13-14. Cf. E. Burgess, *Translation of the Sūrya-Siddhānta*, Calcutta (1935), p. 195. The mean diameters of the planets given in the *Sūrya-Siddhānta*, however, do not agree with those stated in the first verse above.

Reading-differences. In the determination of correct readings I have adopted the same principle as followed by me in the *Mahā-Bhāskarīya.*

English Translation. The English translation supplied by me is as far as possible literal. Where necessary additional explanatory matter is enclosed within brackets. The translation is preceded by a brief gist of the passage translated and is followed where necessary by short notes and comments. To avoid repetition passages having parallels in the *Mahā-Bhāskarīya* have not been commented upon in detail. Parallel passages in the *Mahā-Bhāskarīya* have been indicated in the foot-notes and the reader should refer to them for details. Technical terms are explained in the Glossary given at the end of the book and the reader can conveniently refer to it when necessary.

In the end of this Part, I have added two appendices containing

1. Theory of the pulveriser as applied to problems in astronomy by Bhaṭṭa Govinda.
2. Pāssages from the *Laghu-Bhāskarīya* quoted or adopted in later works.

Contents of the Laghu-Bhāskarīya. The *Laghu-Bhāskarīya,* as its name implies, is the smaller work on astronomy by the author. From the closing stanza of this work, it is clear that the author wrote this work for the benefit of young students with immature mind by condensing and simplifying the contents of his bigger work, called *Mahā-Bhāskarīya* or *Karma-nibandha:*

> "For acquiring a knowledge of the true motion of the planets by those who are afraid of reading voluminous works, the *Karma-nibandha* has been briefly told by Bhāskara."

The *Laghu-Bhāskarīya* is divided into eight chapters. The first chapter contains 37 verses and deals with the calculation of mean longitudes of the planets.

Verse 1 pays homage to the Sun and Verse 2 to Āryabhaṭa I.

Verse 3 is an appreciation of Āryabhaṭa I and his work.

Verses 4-8 give a method for determining the number of days elapsed since the commencement of Kaliyuga (*i.e.*, since mean sunrise at Laṅkā on Friday, February 18, B.C. 3102).

Verses 9-14 state the revolutions of the planets, etc., around the Earth, and the number of civil days in a period of 43,20,000 years.

Verses 15-17 give the general rule for calculating the mean longitudes of the planets, etc.

Verses 18-22 state the positions of the apogees of the planets and the dimensions of the epicycles of the planets.

Verse 23 specifies the position of the Hindu prime meridian.

Verses 24-29 are devoted to the determination of the longitude of a place.

Verse 30 gives the criterion for knowing whether the local place is to the east or to the west of the prime meridian.

Verses 31-36 relate to the longitude correction to the mean longitudes of the planets and its justification and importance.

Verse 37 differentiates between the longitude-correction and the *lambana*-correction.

A detailed treatment of the longitude-correction is a remarkable feature of this chapter. As many as fourteen verses are devoted to this topic only.

The second chapter contains 41 verses and is devoted to the calculation of the true longitudes of the planets.

Verses 1-20 relate to the determination of the Sun's true longitude. Of these, verses 1-4 deal with the Sun's equation of the centre, and the Sun's correction for the equation of time due to the eccentricity of the ecliptic; verse 5 gives approximate formulae for the latter correction in the case

of the Sun and the Moon; verses 6-7 give a rule for finding the true distances of the Sun and the Moon; verses 8-15(ii) relate to the calculation of true daily motion (in longitude) for the Sun and the Moon; verse 16 gives a rule for finding the Sun's declination from the Sun's longitude; verses 17-18 give a rule for finding the Sun's ascensional difference; and verses 19-20 relate to the Sun's correction for the Sun's ascensional difference (*i.e*, for the difference of times of sunrise at the local place and at the place where the local meridian intersects the equator).

Verse 21 gives a rule for finding the lengths of day and night when the Sun is in the northern or southern hemisphere.

Verses 22-24 deal with the corrections for the Moon.

Verses 25-28 relate to the calculation of *nakṣatra*, *tithi*, and *karaṇa*, which form three important elements of the Hindu Calendar.

Verse 29 relates to the classification of the phenomena called *vyatīpāta*. The remaining chapter deals with the planets, Mars, etc.

Verse 30 gives general instructions relating to the planets.

Verses 31-32 relate to the correction to be applied to the tabulated epicycles of the planets.

Verses 33-37(i) give the method for finding the true longitude in the case of Mars, Jupiter and Saturn.

Verses 37(ii)-39 give the corresponding method for Mercury and Venus.

Verse 40 gives the criterion for knowing whether a planet is stationary.

Verse 41 states the method for finding the true daily motion of a planet, direct or retrograde.

The third chapter comprises 35 verses and deals with the determination of directions, time, and place, with the help of the shadow of the gnomon.

Verses 1-2(i) give the method for finding the directions—east, west, north, and south.

Verses 2(ii)-3 give a rule for finding the local latitude from the equinoctial midday shadow.

Verses 4-6 relate to the times of rising of the signs at the equator and at the local place.

Verses 7-11 and 12-15 give rules for finding the Sun's altitude and zenith distance with the help of the time elapsed since sunrise (in the forenoon) or to elapse before sunset (in the afternoon), and *vice versa*.

Verse 16 relates to the determination of the *śaṅkvagra* (*i.e.*, the distance of the Sun's projection on the plane of the celestial horizon, from the Sun's rising-setting line).

Verses 17-19 give a method for finding the longitude of the rising point of the ecliptic with the help of the Sun's instantaneous longitude and the time elapsed since sunrise.

Verse 20 gives a rule for finding the time elapsed since sunrise with the help of the instantaneous longitudes of the Sun and the rising point of the ecliptic.

Verse 21 relates to the determination of the Rsine (=Radius × sine) of the Sun's *agrā* (*i.e.*, the distance between the east-west line and the Sun's rising-setting line).

Verses 22-23 relate to the calculation of the Sun's prime vertical altitude and the derivation of the shadow of the gnomon therefrom.

Verses 24-25 give a rule for finding the Sun's longitude with the help of the prime vertical shadow of the gnomon.

Verse 26 gives a rule for finding the arc corresponding to a given Rsine. [The converse of this was already given in ii. 2(ii)-3(i).]

Verses 27-28 give a rule for finding the Sun's altitude and zenith-distance, and the midday shadow of the gnomon with the help of the Sun's declination and the local latitude.

Verses 29-33 relate to the determination of the Sun's longitude from the midday shadow of the gnomon.

Verse 34 gives a rule for finding the Sun's declination with the help of the local latitude and the Sun's meridian zenith distance.

Verse 35 relates to the determination of the local latitude with the help of the Sun's declination and the midday shadow of the gnomon.

The fourth chapter contains 32 verses and is devoted to the calculation of a lunar eclipse and also to the graphical representation of an eclipse.

Verse 1 gives an approximate rule for finding the longitudes of the Sun and the Moon for the time of geocentric opposition or conjunction of the Sun and Moon.

Verse 2 states the mean distances of the Sun and the Moon, and verse 3 gives a rule for finding their true distances.

Verse 4 states the measures of the diameters of the Sun, Moon, and the Earth.

Verse 5 gives a rule for finding the angular diameters of the Sun and the Moon.

Verses 6-7 relate to the determination of the diameter of the Earth's shadow where the Moon crosses it.

Verse 8 gives a rule for finding the Moon's latitude for the time of opposition of the Sun and Moon.

Verse 9 gives a rule for finding the measure of the Moon's diameter unobscured by the shadow.

Verses 10-13 relate to the determination of the durations of eclipse before and after the time of opposition of the Sun and Moon and of the times of the first and last contacts.

Verse 14 gives a rule for finding the durations of totality before and after the time of opposition of the Sun and Moon.

Verses 15-21 relate to the determination of the so called *valana*, which is required in the construction of the figure of an eclipse.

Verse 22 relates to the conversion of minutes of arc into *aṅgulas*.

Verses 23-30 relate to the construction of the figure of an eclipse.

Verses 31-32 relate to the construction of the phase of an eclipse for the given time.

The fifth chapter consists of 15 verses and deals with the calculation of a solar eclipse.

Verse 1 gives the definition of the so called "local divisor" to be used later.

Verses 2-8(i) relate to the determination of the *dṛkkṣepa-jyā* and *dṛggati-jyā*.

Verses 8(ii)-10 and 11 relate to the determination of the *lambana-ghaṭīs* (*i.e.*, the difference between the parallaxas in longitude of the Sun and Moon, in terms of *ghaṭīs*) and the *nati* (*i.e.*, the difference between the parallaxes in latitude of the Sun and Moon) for the time of apparent conjunction of the Sun and Moon with the help of *dṛkkṣepa-jyā* and *dṛggati-jyā*.

Verse 12 relates to the determination of the Moon's true latitude (*i.e.*, Moon's latitude corrected for parallax) for the same time.

Verses 13-14 give a rule for finding the durations of a solar eclipse before and after the time of apparent conjunction of the Sun and Moon.

Verse 15 gives the condition for the impossibility of a solar eclipse.

The sixth chapter contains 25 verses and deals with the visibility of the Moon, the phases of the Moon including the elevation of the Moon's horns, and the rising and setting of the Moon.

Verses 1-4 deal with the visibility corrections (*akṣa-dṛkkarma* and *ayana-dṛkkarma*).

Verse 5 gives the minimum distance of the Moon from the Sun at which she becomes visible.

Verses 6-7 give a rule for finding the measure of the Moon's illuminated part in the light half of the month and the measure of the Moon's unilluminated part in the dark half of the month.

Verses 8-12(i) relate to the calculation of the base of the elevation triangle.

Verses 12(ii)-18 relate to the construction of the figure exhibiting the elevation of the lunar horns in the first and second quarters of the month.

Verse 19 gives a rule for finding the duration of visibility of the Moon in the light half of the month.

Verses 20-21 relate to the time of rising of the Moon on the full moon day.

Verse 22 relates to the determination of the shadow of the gnomon due to the Moon.

Verses 23-25 gives a rule for finding the time of moonrise in the dark half of the month.

The seventh chapter comprises 10 verses and deals with the visibility and conjunction of the planets.

Verses 1-2 give the minimum distances of the planets from the Sun, in degrees of time, at which they become visible.

Verse 3 gives the method for finding the degrees of time between the Sun and a planet.

Verses 4-5 give a rule for finding the time and common longitude of two neighbouring planets when they are in conjunction in longitude.

Verses 6-9(i) give the method for finding the latitudes of the planets.

Verses 9-10 relate to the determination of the distance between two planets which are in conjunction in longitude.

The eighth chapter is composed of 19 verses and deals with the conjunction of a planet with a star.

Verses 1-4 state the longitudes of the junction-stars of the twenty-seven zodiacal asterisms.

Verse 5 defines the conjunction of a star with a planet.

Verses 6-9 state the latitudes of the junction-stars of the twenty-seven zodiacal asterisms.

Verse 10 relates to the conjunction of the Moon with a star.

Verses 11-16 give the latitudes of the Moon when she occults some of the prominent stars of the zodiac.

Verses 17-18 give two astronomical problems on indeterminate equations.

Verse 19 states the object, scope and authorship of the book.

A comparative study of the contents of the *Mahā-Bhāskarīya* and the *Laghu-Bhāskarīya* confirms the author's claim that the latter work is an abridgement of the former. The *Laghu-Bhāskarīya* is, truly speaking, a well-planned summary of the *Mahā-Bhāskarīya*, in which the unnecessary or irrelevant rules have been omitted, the defective or erroneous rules have been rectified or replaced, and some new rules which were considered important for the beginner have been added.

The following table provides a comparative analysis of the rules occurring in the two works. It will show at a glance which of the rules of the *Mahā-Bhāskarīya* occur in the *Laghu-Bhāskarīya* in abridged or modified form, or have been omitted in the *Laghu-Bhāskarīya*, or which of the rules of the *Laghu-Bhāskarīya* have no counterpart in the *Mahā-Bhāskarīya*.

Comparative Analysis of the rules of the Laghu-Bhāskarīya and the Mahā-Bhāskarīya

Laghu-Bhāskarīya	*Mahā-Bhāskarīya*	*Laghu-Bhāskarīya*	*Mahā-Bhāskarīya*
i. 4-8	i. 4-6: vii. 6-7	—	i. 13-19
i. 9-14	vii. 1-5, 8	—	i. 20
i. 15-17	i. 8, 40	—	i. 21-39
i. 18, 19-21, 22	vii. 11, 12 i), 13-16	—	i. 41-52
i. 23	ii. 1-2	—	ii. 8
i. 24	ii. 10(iii)	ii. 1-2(i)	iv. 1; 8(i)
i. 25-26	ii. 3-4	ii. 2(ii)-3(i)	iv. 3-4(i)
i. 27	ii. 5	ii. 3(ii)-4(i)	iv. 6
i. 28	ii. 6	ii. 4(ii)	iv. 7
i. 29	ii. 7	ii. 5	—
i. 30	ii. 9	ii. 6-7	iv. 9-12
i. 31	ii. 10(i)	ii. 8	iv. 13
i. 32	ii. 10(ii)	ii. 9-10	iv. 14
i. 33	—	ii. 11-13	iv. 15-17
i. 34	—	ii. 14-15(i)	—
i. 35	—	ii. 15(i)	iv. 18
i.36	—	ii. 16	iii. 6(i)
i. 37	—	ii. 17-18	iii. 6(ii)-7
—	i. 7	ii. 19-20	iv. 26-27
—	i. 9	ii. 21	iv. 28
—	i. 10	ii. 22-24	iv. 29-30
—	i. 11-12	ii. 25-26(i)	iv. 34

Laghu-Bhāskarīya	*Mahā-Bhāskarīya*	*Laghu-Bhāskarīya*	*Mahā-Bhāskarīya*
ii. 26(ii)-27	iv. 31-32	iii. 4	iii. 8
ii. 28	iv. 33	iii. 5	iii. 10 (i)
ii. 29	iv. 35	iii. 6	iii. 10(ii)
ii. 30	iv. 37	iii. 7-10	iii. 18-20
ii. 31-32	iv. 38-39	iii. 11(i)	iii. 25
ii. 33-37(i)	iv. 40-43	iii. 11(ii)	iii. 26
ii. 37(ii)-39	iv. 44	iii. 12-15	iii. 27-28($\frac{1}{4}$)
ii. 40	—	iii. 16	iii. 54
ii. 41	—	iii. 17-19	iii. 30-32
—	iv. 2	iii. 20	iii. 34-36
—	iv. 4(ii)-5	iii. 21	iii. 37
—	iv. 19-20	iii. 22-23	iii. 37-38
—	iv. 21-23	iii. 24-25	iii. 41
—	iv. 24	iii. 26	viii. 6
—	iv. 25	iii. 27-28	iii. 11
—	iv. 36	iii. 29-33	iii. 13-16
—	iv. 45-46	iii. 34	—
—	iv. 47	iii. 35	iii. 17
—	iv. 48-54	—	iii. 3
—	iv. 55	—	iii. 9
—	iv. 56-57	—	iii. 12
—	iv. 58-63	—	iii. 21-24
iii. 1	iii. 1-2	—	iii. 29
iii. 2-3	iii. 4-5(i-iii)	—	iii. 33

Laghu-Bhāskarīya	*Mahā-Bhāskarīya*	*Laghu-Bhāskarīya*	*Mahā-Bhāskarīya*
—	iii. 39	iv. 18	v. 46-47(i)
—	iii. 40	iv. 19	v. 47(ii)
—	iii. 42-45	iv. 20	—
—	iii. 46-51	iv. 21	v. 54(i), 77
—	iii. 52	iv. 22	v. 53(ii)
—	iii. 53	iv. 23-30	v. 48-58, 61
—	iii. 55	iv. 31-32	v. 62-65
—	iii. 56-60(i)	—	v. 6-7
—	iii. 60(ii)-61	—	v. 32
—	iii. 62	—	v. 40
iv. 1	iv. 64	—	v. 41
iv. 2	v. 2	—	v. 59-60
iv. 3	v. 3	—	v. 66-67, 68-70
iv. 4	v. 4	v. 2-4(i)	v. 8-11
iv. 5	v. 5	v. 1, 4(ii)-7(i)	v. 12-23
iv. 6	v. 71,72(i)	v. 8(ii)-10	v. 24-27
iv. 7	v. 72(ii)-73	v. 11	v. 28-29
iv. 8	v. 30-31(i)	v. 12	v. 31(ii)
iv. 9	—	v. 13-14	v. 34-39
iv. 10-12	v. 74-76(i)	v. 15	v. 33
iv. 13	v. 35	vi. 1-2	vi. 1-2(i)
iv. 14	v. 76(ii)	vi. 3-4	vi. 2(ii)-3
iv. 15-16	v. 42-44	vi. 5	vi. 4(ii)-5(i)
iv. 17	v. 45	vi. 6-7	vi. 5(ii)-7

Laghu-Bhāskarīya	*Mahā-Bhāskarīya*	*Laghu-Bhāskarīya*	*Mahā-Bhāskarīya*
vi. 8-12(i)	vi. 8-12	—	vi. 32-38
vi. 12(ii)-17	vi. 13-17	—	vi. 39-41
vi. 18	vi. 19	—	vi. 42
vi. 19	vi. 27	—	vi. 45
vi. 20-21	vi. 22	—	vi. 56-60
vi. 22	—	—	vii. 17-19
vi. 23-25	vi. 28-31	—	vii. 20-35
vii. 1-2	vi. 44, 46(i)	viii. 1-4	iii. 63-66(i)
vii. 3	vi. 46(ii)-47	viii. 5	iii. 70(ii)
vii. 4-5	vi. 49-51	viii. 6-9	viii. 66(ii)-70(i)
vii. 6-10	vi. 48, 52-55; vii. 9-10	viii. 10	—
—	vi. 18	—	iii. 71 (i)
—	vi. 20-21	viii. 11-16	iii. 71(ii)-75(i)
—	vi. 23-26	viii. 17-18	—

The arrangement o f the contents of the *Laghu-Bhāskarīya* is more systematic and logical than that of the *Mahā-Bhāskarīya* and is, at the same time, in keeping with the general practice followed by the other Hindu astronomers.

Popularity of the Laghu-Bhāskarīya. In Part I, I have shown that both the *Mahā-Bhāskarīya* and the *Laghu-Bhāskar ya* were popular works, having been studied in south India up to the end of the fifteenth century A. D., the former due to its being an authoritative work on Āryabhaṭa I's system of astronomy and the latter being an excellent text-book for beginners in astronomy.

Evidence of popularity of the *Laghu-Bhāskarīya* is furnished by the numerous quotations from this work that are found to

occur in the annotative works of Sūryadeva (b. 1191 A.D.), Yallaya (1480 A.D.), Nīlakaṇṭha (1500 A.D.), Raghunātha Rāja (1597 A.D.), Govinda Somayājī and Viṣṇu Śarmā, and in the *Prayoga-racanā*, an anonymous commentary on the *Mahā-Bhāskarīya*. Quotations from the *Laghu-Bhāskarīya* are found to occur not only in astronomical and astrological works but also in works on other subjects. For example, one quotation occurs in Karavinda Svāmī's commentary on the *Āpastamba-śulba-śūtra*. Some passages from the *Laghu-Bhāskarīya* have also been adopted verbatim or with slight verbal alterations in the *Tantra-saṅgraha* of Nīlakaṇṭha (1500 A. D.). A list of passages quoted or adopted in later works is given in Appendix 2 at the end of this book.[1]

Another evidence of the popularity of the *Laghu-Bhāskarīya* is the occurrence of commentaries on this work, written in Sanskrit as well as in provincial vernaculars, such as Malayālam and Tamil. Amongst the notable commentators may be mentioned the names of Śaṅkaranārāyaṇa (869 A. D.), Udayadivākara (1073 A. D.) and Parameśvara (1408 A.D.).

Authorship. The author of the *Laghu-Bhāskarīya* bears the name Bhāskara as is evident from the closing stanzas of his works, the *Mahā-Bhāskarīya* and the *Laghu-Bhāskarīya*. But he is a different person from his namesake of the twelfth century A. D., the celebrated author of the *Siddhānta-śiromaṇi*, *Līlāvatī*, and *Bījagaṇita*, etc. He lived in the seventh century of the Christian era and was a contemporary of Brahmagupta (628 A. D.). To distinguish between the two Bhāskaras, I have called the author of the *Mahā-bhāskarīya* and the *Laghu-Bhāskarīya* by the name Bhāskara I and the author of the *Siddhānta-śiromaṇi* by the name Bhāskara II.

[1] See pp. 115-119.

In addition to the two works mentioned above, Bhāskara I wrote one more work on astronomy, viz. a commentary on the *Āryabhaṭīya*. In Part I, I have shown that the three works of Bhāskara I were written in the following chronological order:

(1) The *Mahā-Bhāskarīya*

(2) Commentary on the *Āryabhaṭīya*

(3) The *Laghu-Bhāskarīya*

At two places in the commentary on the *Āryabhaṭīya*, Bhāskara I has mentioned the time elapsed since the beginning of the current *Kalpa* (Aeon). Thus in his commentary on the eighth *gītikā-sūtra* (*Ā*, i. 9), he writes:

> "Since the beginning of the (current) *Kalpa* (Aeon) the number of years elapsed is this: zero, three, seven, three, twelve, six, eight, nine, one (proceeding from right to left) years. The same (years) in figures are 1986123730."[1]

Under the same *gītikā-sūtra*, he again writes:

> "The time elapsed, in terms of years, since the commencement of the (current) *Kalpa* is zero, three, seven, three, twelve, six, eight, nine, one (years). The same (years written in figures) are 1986123730."[2]

Now the number of years elapsed since the beginning of the current *Kalpa* at the commencement of Kaliyuga[3]

$$= 6 \textit{ manus} + 27\tfrac{3}{4} \textit{ yugas}$$
$$= 6 \times 72 \textit{ yugas} + 27\tfrac{3}{4} \textit{ yugas}$$
$$= (432 + 111/4) \times 4320000 \text{ years}$$
$$= (1866240000 + 119880000) \text{ years}$$
$$= 1986120000 \text{ years.}$$

---

[1] कल्पादेरब्दनिरोधादयं अब्दराशिरितीरितः खाग्यद्रिरामार्करसवसुरन्ध्रेन्दवः ।
ते चाङ्कैरपि 1986123730.

[2] कल्पादेरब्दनिरोधात् गतकालः खाग्न्यद्रिरामार्करसवसुरन्ध्रन्दवः ।
ते च 1986123730.

[3] See *Ā*. i. 5.

Therefore the number of years elapsed since the beginning of Kaliyuga at the time of writing the commentary

$$= 1986123730 - 1986120000 \text{ years}$$
$$= 3730 \text{ years.}$$

The year when 3730 years of Kaliyuga had elapsed was the year 629 of the Christian era. Bhāskara I's commentary on the *Āryabhaṭīya* was, therefore, written in 629 A. D., *i.e.*, exactly one year after Brahmagupta wrote his *Brāhma-sphuṭa-siddhānta*. The *Mahā-Bhāskarīya* was written earlier and the *Laghu-Bhāskarīya* later than this date.

The place of birth and activity of Bhāskara I is not definitely known. On the basis of circumstantial evidence supplied by his works I have shown in Part I that he had associations with the countries of Aśmaka and Surāṣṭra. His commentary on the *Āryabhaṭīya* was probably written in the city of Valabhī in Surāṣṭra. It may be that Bhāskara I was born and educated in Aśmaka and migrated to Valabhī where he wrote his commentary on the *Āryabhaṭīya*, or that he was a native of Valabhī and got his education in the Aśmaka country. (For details, see Part I).

Bhāskara I has a special predilection for calling Āryabhaṭa I by the name *Āśmaka*, his *Āryabhaṭīya* by the name *Āśmaka-tantra* or *Āśmakīya*, and his followers by the epithet *Āśmakīyāḥ*. Preference for these unusual names to the usual ones seems to suggest that either Bhāskara I belonged to the Aśmaka country or that there was a school of astronomy in that country whose exponents where "followers of Āryabhaṭa" and to which Bhāskara I himself belonged. As Datta has observed,[1] Bhāskara I was undoubtedly the most competent exponent of Āryabhaṭa I's school of astronomy (the Aśmaka school). (For details, see Part I).

---

[1] B. Datta, "The Two Bhāskaras," *Indian Historical Quarterly*, Vol. VI, 1930, pp. 727-736.

The Aśmaka country (or Aśmaka Janapada) is mentioned in both Hindu and Buddhist literatures, where it means either (i) a country in the north-west of India, or (ii) a country lying between the rivers Narmadā and Godāvarī. The Aśmaka of Bhāskara I was evidently the latter one.

As regards the personal history of Bhāskara I, it appears from his works that he was a Brāhmaṇa, a worshipper of God Śiva. He seems to have been a teacher by profession, in which capacity he earned a great name and fame. Later writers have shown their respect to him by addressing him by the epithet *guru*. Thus Śaṅkaranārāyaṇa, in the beginning of his commentary on the *Laghu-Bhāskarīya*, says :

> "Having paid homage by lowering my head to Ācārya Āryabhaṭa, Varāhamihira, *śrīmadguru* Bhāskara, Govinda, and Haridatta, one after the other, I give out..."[1]

So also says Udayadivākara :

> "Having bowed to Murāri, the Lord of the entire world, and also having paid respectful homage to Ācārya Āryabhaṭa, I write an extensive exposition of the smaller work on astronomy composed by *guru* Bhāskara."[2]

The professional ability of Bhaskara I is clearly evinced by his works which were studied in India up to the end of the fifteenth century A. D. (or even after) and on which a number of commentaries were written. His commentary on the *Āryabhaṭīya*, in particular, has been recognized as a work of great scholarship, and he has been called *sarvajña bhāṣyakāra* ("all-knowing commentator").

---

[1] आचार्यार्यभटं वराहमिहिरं श्रीमद्गुरुं भास्करम् ।
गोविन्दं हरिदत्तमत्र शिरसा वक्ष्ये प्रणम्य क्रमात् ।।

[2] नत्वा समस्तजगतामधिपं मुरारि-
माचार्यमार्यभटमप्यभिवन्द्य भक्त्या ।
यद् भास्करेण गुरुणा ग्रहतन्त्रमुक्तं
लघ्वस्य विस्ततरां विवृतिं विधास्ये ।।

Though essentially an astronomer and mathematician, Bhāskara I, in his commentary on the *Āryabhaṭīya*, displays a thorough knowledge of Sanskrit grammer and Vedic literature in general, and seems to be well-read in other branches of Sanskrit learning also.

As an astronomer Bhāskara I was a follower of Āryabhaṭa I and, as already mentioned, belonged to the Aśmaka school of astronomy. His works put before us a complete and clear picture of the teachings of Ācārya Āryabhaṭa I and throw fresh light on the development of astronomy during the sixth and seventh centuries A. D. His works are thus of special significance to historians of Hindu mathematics and astronomy, who are now in a position to have a clear glimpse of the astronomical conditions prevailing in the sixth and seventh centuries A. D. in the Aśmaka country which was the main seat of Āryabhaṭa I's system of astronomy. In the absence of the works of Bhāskara I, many a passage in the *Āryabhaṭīya* of Āryabhaṭa I would have remained obscure to us.

In conclusion I take the opportunity to express my sincere thanks to Dr. Ram Ballabh, Professor of Mathematics, Lucknow University, for taking keen interest in my work and offering helpful suggestions and advice from time to time, and for affording all facilities in my researches.

I must also express my thanks to my Research Assistant, Sri Markandeya Misra, Jyotisacharya, for the assistance rendered by him to me.

My thanks are also due to Sri R. Chandra of Star Press, Lucknow, for their unfailing courtesy and care in the printing of this book.

K. S. Shukla

लघुभास्करीयम्

श्रीमद्भास्कराचार्यप्रणीतम्

लघुभास्करीयम्

प्रथमोऽध्यायः

भास्कराय नमस्तस्मै[1] स्फुटेयं ज्योतिषां गतिः ।
प्रक्रियान्तरभेदेऽपि[2] यस्य गत्याऽनुमीयते ॥ १ ॥
काले महति देशे वा स्फुटार्थं[3] यस्य दर्शनम् ।
जयत्यार्यभटः सोऽब्धिप्रान्तप्रोल्लङ्घिसद्यशाः[4] ॥ २ ॥
नालमार्यभटादन्ये[5] ज्योतिषां गतिवित्तये ।
तत्र[6] भ्रमन्ति तेऽज्ञानबहलध्वान्तसागरे[7] ॥ ३ ॥
नवाद्रयेकाग्निसंयुक्ताः[8] शकाब्दा द्वादशाहताः ।
चैत्रादिमाससंयुक्ताः पृथग्गुण्या[9] युगाधिकैः ॥ ४ ॥
ते च षट्त्रिकरामाग्निनवभूतेन्दवो युगे ।
भागहारोऽब्धिवस्वेकशराः स्युरयुताहताः ॥ ५ ॥
अधिमासान्पृथक्स्थेषु प्रक्षिप्य त्रिंशताहते ।
युक्त्वा[10] दिनानि यातानि प्रतिराश्य युगावमैः ॥ ६ ॥
सङ्गुणय्या[11]म्बराष्टेषुद्व्यष्टशून्यशराश्विभिः ।
छेदः खाष्टवियद्व्योमखखाग्निखरसेन्दवः[12] ॥ ७ ॥

---

[1] नमस्तुभ्यं B, P. [2] प्रक्रियातदभेदेऽपि A. [3] स्फुटार्था A. [4] सोऽब्धिप्रान्तप्रोल्लाघिसद्यशाः A. Udaya Divākara refers to the reading वार्धि in place of सोऽब्धि. [5] अलमार्यभटादन्ये B. [6] यत्र A, C. [7] ते ज्ञानबहुलभ्रान्तिसागरे A. [8] नवाद्र्येकाग्निसायुक्ताः A; नवाद्रीन्द्वग्निसंयुक्ताः C. [9] पृथ..... D. [10] युङ्क्त्वा C. [11] सगुणस्या A. [12] काष्ठविय° A. The second line of this verse is missing from D.

लब्धान्यवमरात्राणि तेषु शुद्धेष्वहर्गणः ।
वारः सप्तहृते शेषे शुक्रादिर्भास्करोदयात् ॥ ८ ॥

दस्राग्निसागरा भानोरयुतघ्नाः[1] निशाकृतः ।
अङ्गपुष्कररामाग्निशरशैलाद्रिसायकाः[2] ॥ ९ ॥

कौजा[3] वेदाश्विवस्वङ्गनवदस्रयमा[4] गुरोः ।
सागराश्वियमाम्भोधिरसरामाः[5] प्रकीर्तिताः ॥ १० ॥

शनेरपि च वेदाङ्गभूतषट्कसुराधिपाः ।
सावित्रा[6] राजपुत्रस्य भगणा भार्गवस्य[7] च ॥ ११ ॥

इन्दूच्चस्य नवैकाश्विवसुप्रकृतिसागराः ।
बौधाः खाश्विखसप्ताग्निरन्ध्रशैलनिशाकराः[8] ॥ १२ ॥

भार्गवस्याष्टवस्वग्नियमदस्राम्बराद्रयः[9] ।
मध्यमो भास्करः[10] शीघ्रः[11] शेषाणां पातपर्ययाः[12] ॥ १३ ॥

अङ्गाश्वियमदस्राग्नियमलाः भूदिनानि तु ।
व्योमशून्यशराद्रीन्दुरन्ध्राद्र्यद्रिशरेन्दवः[13] ॥ १४ ॥

पर्ययाहर्गणाभ्यासो[14] ह्रियते[15] भूदिनैस्ततः ।
लभ्यन्ते पर्ययाः शेषाद्राशिभागकलादयः ॥ १५ ॥

भास्करैस्त्रिशता षष्ट्या सङ्गुणय्य पृथक् पृथक् ।
तेनैव भागहारेण लभ्यन्तेऽर्कोदयावधेः[16] ॥ १६ ॥

विलिप्तान्ता ग्रहा मध्याः शश्युच्चे[17] राशयस्त्रयः ।
क्षिप्यन्ते षट् तमोमूर्तौ[18] चक्रात् स च विशोध्यते[19] ॥ १७ ॥

शतमष्टादशोपेतं द्विशती दशसंयुता ।
चक्रार्धभागा[20] नवतिः षट्त्रिदस्राः कुजादितः[21] ॥ १८ ॥

---

[1] दानोर° A. [2] अङ्गपुष्कररामाग्निशरखैः प्राद्रिसायकाः A. [3] तौजा A. [4] खेदाश्वि° A. [5] सागरोऽश्वि° A. [6] सवित्रा D. [7] भास्करस्य A. [8] °रस्त्रशैल° A. [9] °ग्निनवदस्राम्बरादयः B. [10] भास्करो मध्यमः C. [11] शीघ्रः is missing from D. [12] पातपयया D. [13] °रखाद्यद्रि° A. [14] पर्याया° P. [15] क्रियते C. [16] °न्तेतोदया° A. [17] शश्य····· A. [18] तमोमुक्तेः A. [19] विशोधयेत् A. [20] चक्रेऽर्धभागा D. [21] °दस्रकुजाभितः B.

मन्दाः सुराधिपाः सप्त शैला[1] जलधयो नव ।
अष्टादश च पञ्चाष्टौ द्वौ च युग्मे त्रयोदश ॥ १९ ॥

पञ्चाशत् त्रिकसंयुक्ता[2]स्त्रिंशद्रूपेण संयुताः ।
षोडशैकोनषष्टिश्च शीघ्रा[3] नव च कीर्तिताः ॥ २० ॥

द्वाभ्यां द्वाभ्यामथैकेन द्वाभ्यामेकेन वर्जिताः ।
त एव स्युः क्रमाद्युग्मे दृष्टाः परिधयो निजाः ॥ २१ ॥

भास्करस्यापि मन्दांशाः[4] सप्ततिर्वसुसंयुताः[5] ।
परिधिश्च त्रिकस्तस्य[6] सप्त चामृततेजसः ॥ २२ ॥

लङ्कावात्स्यपुरावन्तीस्थानेश्वरसुरालयान्[7] ।
अवगाह्य स्थिता रेखा देशान्तरविधायिनी ॥ २३ ॥

लम्बकेनाहतं[8] भूमेर्नवरन्ध्राश्विवह्नयः[9] ।
व्यासार्धापहृतं वृत्तं[10] स्वदेशे तत्प्रकीर्त्यते ॥ २४ ॥

समरेखास्वदेशाक्षविश्लेषान्तरसङ्गुणम्[11] ।
वृत्तं स्वदेशजो[12] भूमेर्बाहुश्चक्रांशकोद्धृतम्[13] ॥ २५ ॥
कर्णः[14] स्वदेशतस्तिर्यक्[15] समरेखावधेः[16] स्थितः[17] ।
तद्बाहुवर्गविश्लेषमूलं देशान्तरं स्मृतम्[18] ॥ २६ ॥

इत्याहुः केचिदाचार्या[19] नैवमित्यपरे जगुः[20] ।
स्थूलत्वात्कर्णसङ्ख्याया वक्रत्वात्परिधेर्भुवः ॥ २७ ॥

मध्यच्छायादिनार्धोत्थतिग्मरश्म्योर्यदन्तरम्[21] ।
न तत्फलस्य[22] तुल्यत्वात्समपूर्वापराशयोः[23] ॥ २८ ॥

---

[1] शैला is missing from C. [2] पञ्चाशत्त्रिकसंयुक्ता B. [3] शीघ्रे B, C. [4] मन्दांशा B; मन्दांशः C. [5] °युता B, C. [6] त्रिको यस्य A. [7] लङ्कामात्स्य-पुरावन्तिस्थानेश्वरसुरालयात् A; °स्थानैश्चर° B; °वन्ति° C, D; °मात्स्यपुरावन्ति° P. [8] °हता A. [9] °खाद्रयः A. [10] °हृता वृत्ताः A. [11] °खासदेशाक्षविश्लेषान्तर-सङ्गुणा A; °न्तसङ्गु° D. [12] वृत्तास्स्वदेशजा A; स्वदेशजं B, C, D. [13] °द्धृतः A, C, D, P. [14] तत्र C; कर्णं B, D. [15] °तियक् D. [16] °वधौ A. [17] स्थिता D. [18] °न्तरा स्मृता A. [19] °दाचार्यो B. [20] विदुः A. [21] °तिग्मराश्योर्यं° A; °नार्धोत्थं तिग्म° D. [22] तत्फल° A, B, C, D, P. [23] °परांशयोः A.

गणितप्रक्रियावाप्तप्रत्यक्षीकृतकालयोः[1] ।
विश्लेषो यो ग्रहणयोः[2] कालो[3] देशान्तरस्य सः ॥ २९ ॥

अतीत्य गणितानीतं[4] यदा स्यातामुपप्लुती[5] ।
पूर्वेण समरेखाया द्रष्टा स्यात् पश्चिमेऽन्यथा[6] ॥ ३० ॥

देशान्तरघटीक्षुण्णा मध्या भुक्तिर्भुचारिणाम्[7] ।
षष्ट्या भक्तमृणं प्राच्यां[8] रेखायाः पश्चिमे धनम् ॥ ३१ ॥

स्वदेशभूमिवृत्तेन[9] हृत्वा देशान्तरा घटीः[10] ।
षष्ट्या विभज्य लभ्यन्ते योजनानि स्वदेशतः ॥ ३२ ॥

योजनैर्मध्यमां भुक्तिं हृत्वा तद्देशजैः सदा[11] ।
स्वभूवृत्तेन यल्लब्धं[12] शोध्यं क्षेप्यं स्वमध्यमे[13] ॥ ३३ ॥

देशान्तरघटीभोगप्रक्षेपापचयौ विधिः ।
ऊनाधिकतिथेर्हेतुस्तेन दृष्टं न हीयते ॥ ३४ ॥

मोक्ष्यमाणे तु शीतांशौ[14] नाडिकायामिहास्तगे[15] ।
मुक्त्वाऽस्तं[16] पश्चिमे यातः[17] प्राच्यां[18] प्राहुस्तदा ग्रहः[19] ॥ ३५ ॥

विपरीतधनर्णत्वे यथा दृष्टा[20] तिथिर्न सा ।
अन्यथा प्रक्रियाप्राप्तिर्गत्यन्यत्वं[21] ग्रहस्य च[22] ॥ ३६ ॥

धनर्णे स्तस्तिथेस्तस्य[23] कालस्येन्द्वर्कयोस्ततः ।
लम्बनस्यैव[24] नात्र स्याद्युक्तिर्देशान्तरस्य सा ॥ ३७ ॥

इति लघुभास्करीये प्रथमोऽध्यायः ।

---

[1] °प्रक्रियाप्राप्त° P. [2] विश्लेषो ग्रहणं योर्यः B. [3] काले B. [4] तं is missing from A. [5] °प्लुतिः A. [6] भ्रष्टा स्यात्प° A; द्रष्टास्याः प° C. [7] °भुक्तिर्विचा° B; मध्यभुक्ति° P. [8] भक्तमृणप्राच्या A. [9] सन्देशभुविवृत्तेन A. [10] घटिः A; हृत्वा देशान्तरा घटीः is missing from B. [11] हृत्वा तद्देशजैः सदा is missing from B. [12] भूवृत्तेन तु य° A; स्वभूवृत्तेन यत् is missing from B. [13] च मध्यमे B. [14] शितांशौ P. [15] नाडिकायामथास्तके A. [16] मुक्तास्तं B. [17] पश्चिमे यातं A; °मे याताः B; °मायाताः C. [18] प्राच्याः B, C. [19] प्रागुदयाद्ग्रहम् A; प्राहुस्तथा ग्रहाः B. [20] दृष्ट्वा A; दृष्टिः C. [21] प्रक्रियावाप्तिर्गत्यवत्त्व A. [22] तु D. [23] धनर्णेऽस्तास्थितेतस्य A; धनर्णस्ते तिथेस्तस्या B; °स्तिथेस्तद्वत् C. [24] °नस्येव A, B.

द्वितीयोऽध्यायः

मध्यमं पद्मिनीबन्धोः केन्द्रमुच्चेन वर्जितम्[1] ।
पदं[2] राशित्रयं तत्र भुजाकोटी[3] गतागते ॥ १ ॥
ओजे युग्मे क्रमाज्ज्ञेये कोटिबाहू[4] इति स्थितिः ।
लिप्तीकृत्य[5] धनुर्भागैर्जीवाः[6] कल्प्या[7] भुजेतराः[8] ॥ २ ॥
वर्तमानाहतं शेषं धनुषाप्तं[9] विनिक्षिपेत् ।
ते परिघ्याहतेऽशीत्या लब्धे कोटिभुजाफले ॥ ३ ॥[10]
भुजाफलं[11] धनर्णं[12] स्यात् केन्द्रे जूकक्रियादिके[13] ।
भुजाफलहते भोगे[14] चक्रलिप्ताप्तमेव[15] च ॥ ४ ॥
भुजाफलस्य षड्भागस्तिग्मांशोर्वा विलिप्तिकाः[16] ।
त्रिरभ्यस्ता[17] द्व्यशीत्याप्ता लिप्तिकाद्या[18] निशाकृतः ॥ ५ ॥
कोटिसाधनयुक्तोनं व्यासार्धं मृगकर्कितः[19] ।
तद्बाहुवर्गसंयोगमूलं कर्णः[20] फलाहतः[21] ॥ ६ ॥
व्यासार्धाप्तफलावृत्त्या कर्णः कार्योऽविशेषितः[22] ।
शीतांशोरप्ययं ज्ञेयो विधिः कर्णविशेषणे[23] ॥ ७ ॥
व्यासार्धसङ्गुणा भुक्तिर्मध्या[24] कर्णेन लभ्यते ।
स्फुटभुक्तिः सहस्रांशोः शीतांशोरप्ययं विधिः ॥ ८ ॥
अन्त्यमौर्वीहतां भुक्तिं मध्यमां धनुषा हरेत्[25] ।
लब्धं स्ववृत्तसंक्षुण्णं[26] छित्वाऽशीत्या[27] विशोधयेत् ॥ ९ ॥

---

[1] वर्जिता A. [2] पदा A. [3] भुजाकोटि A, D; भुजकोटी B. [4] कोटिवाह्य B. [5] ज्ञप्तिकृ° A. [6] धनुर्भागे जीवाः P. [7] कल्य A; कथ्या D. [8] °तरा A, C, D. [9] वर्तमानाहता शेषा धनुषाप्ता A. [10] This verse is missing from B, but it has been commented upon by Śaṅkaranārāyaṇa and occurs in all other Mss. [11] भुजावाप्तं B, C. [12] धनं हि C. [13] °यादिगे A. [14] भागे A. [15] वक्रिलिप्ता° A. [16] °र्वापि लिप्तिकाः A. [17] त्रिरभ्यस्य A, B; त्रिकाभ्यस्ता C. [18] °काद्यां P. [19] °र्कतितम् D. [20] कर्म A. [21] फलाहतः is missing from D. [22] कर्णः कार्यो विशेषतः A; कर्णकोट्योर्विशेषजः B. [23] कर्णविशेषणैः A, B; कर्णविशेषणे D; कर्णोविशेषजः P. [24] भुक्तिर्मध्यः P. [25] धनुराहरेत् B. [26] लब्धा स्ववृत्तसंक्षुण्णा A. [27] हृत्वा° A; हृत्वां D.

मकरादिस्थिते केन्द्रे कर्कटादौ तु योजयेत्[१] ।
मध्यभुक्तौ सहस्रांशोः स्फुटभुक्तिरुदाहृता ॥ १० ॥

उत्क्रमक्रमतो ग्राह्याः पदयोरोजयुग्मयोः ।
वर्तमानगुणादिन्दोः केन्द्रभुक्तेः कलावशात् ॥ ११ ॥

आद्यन्तधनुषोर्ज्ञेयं[२] फलं त्रैराशिकक्रमात्[३] ।
गतगन्तव्यधनुषी केन्द्रभुक्तेर्विशोधयेत् ॥ १२ ॥

इत्थमाप्तगुणं हृत्वा वृत्तेनाशीतिसंहृतम् ।
प्राग्वत् क्षयोदयाविन्दोर्मध्ये भोगे स्फुटो मतः[४] ॥ १३ ॥

अभिन्नरूपता भुक्तेश्चापभागविचारिणः[५] ।
रवेरिन्दोश्च जीवानामूनभावाद्यसंभवात्[६] ॥ १४ ॥

एवमालोच्यमानेयं[७] जीवाभुक्तिर्विशीर्यते[८] ।
कर्णभुक्तिस्स्फुटाह्वोर्वा विश्लेषस्स्फुटयोर्द्वयोः[९] ॥ १५ ॥

सप्तरन्ध्राग्निरूपाणि परमापक्रमो गुणः ।
तत्स्फुटार्कभुजाभ्यासस्त्रिज्ययेष्टापमो[१०] हृतः[११] ॥ १६ ॥

तद्वर्गव्यासकृत्योर्यद्विश्लेषस्य[१२] पदं[१३] भवेत् ।
स्वाहोरात्रार्धविष्कम्भः[१४] पलज्येष्टापमाहता[१५] ॥ १७ ॥

क्षितिज्या लम्बकेनाप्ता व्यासार्धेनाहता हृता ।
स्वाहोरात्रेण यल्लब्धं[१६] चरजीवार्धमिष्यते[१७] ॥ १८ ॥

तच्चापलिप्तिकाः प्राणाः स्फुटभुक्त्या समाहताः[१८] ।
खखषड्घनभागेन लभ्यन्ते लिप्तिकादयः ॥ १९ ॥[१९]

---

[१] चयो भवेत् B. [२] °धनुषो ज्ञेया A; आद्यर्धं धनुषो° C. [३] °राशिकंक्र° B, C, D. [४] °र्मध्यभोगः स्फु° A; °र्मध्यभोगे° C, D. [५] अभिन्नरूपतो भुक्तेश्चापभोग° P. [६] °भावादिसं° A. [७] °मानायां A. [८] °क्तिर्विशिष्यते A. [९] कर्णभुक्तिः स्फुटानां वा विश्लेषं A; कर्णभुक्तिस्फुटाह्वो° C; कर्णभुक्तिस्फुटाहौर्वा° D; कर्णभुक्तिस्फुटाह्वोर्वा विश्लेषस्फु° P. [१०] °भ्यासात्त्रिज्ययापक्रमो A; °ष्टावमो C, P; °भ्यासं त्रिज्ययेष्टावमो D. [११] हृतम् P. [१२] °कृत्योस्तु विश्ले° P. [१३] पदा A. [१४] °ष्कम्भं A. [१५] फलज्येष्ठाव-माहता A; पलज्येष्टावमाहता C; °ज्येष्ठाप° D; °ज्येष्ठावमा° P. [१६] यल्लब्धा A. [१७] चरं जीवा° P. [१८] तस्यावलिप्तिकाः प्राणाः स्फुटभुक्तिसमाहताः A. [१९] This verse is missing from B.

उदग्गोलोदये शोध्या देया याम्ये विवस्वति ।
व्यत्ययोऽस्तस्थिते[१] कार्यो न मध्याह्नार्धरात्रयोः ॥ २० ॥

उदग्गोले द्विरभ्यस्तैश्चीयतेऽह्नश्चरासुभिः[२] ।
निशाऽपचीयते[३] तत्र गोले याम्ये विपर्ययः[४] ॥ २१ ॥

भास्वद्भुजाफलाभ्यस्ता[५] मध्या भुक्तिर्निशाकृतः[६] ।
रविवच्चक्रलिप्ताप्तमिन्दुमध्ये[७] धनक्षयौ ॥ २२ ॥

चरप्राणै रवेर्हत्वा[८] स्फुटभुक्तिं निशाकृतः[९] ।
अहोरात्रासुभिश्छित्वा[१०] यत् फलं लिप्तिकादि तत्[११] ॥ २३ ॥

धनक्षयौ स्फुटे चन्द्रे भास्करस्य वशात्सदा ।
आदित्यकर्मणा तुल्यं शेषमिन्दोर्विधीयते ॥ २४ ॥

लिप्तीकृतो निशानाथः शतैर्भाज्योऽष्टभिः फलम् ।
अश्विन्यादीनि भानि स्युः षष्ट्या हृत्वा गतागतम्[१२] ॥ २५ ॥

गतगन्तव्यनाड्यस्ताः[१३] स्फुटभुक्त्योदयावधेः ।
अर्कहीनो निशानाथो लिप्तीकृत्य विभज्यते ॥ २६ ॥

शून्याश्विपर्वतैर्लब्धास्तिथयो[१४] या गताः क्रमात् ।
भुक्त्यन्तरेण लभ्यन्ते[१५] षष्ट्या हृत्वा[१६] गतागतम्[१७] ॥ २७ ॥

तिथ्यर्धहारलब्धानि करणानि बवादितः[१८] ।
विरूपाणि सिते पक्षे[१९] सरूपाण्यसिते[२०] विदुः ॥ २८ ॥

सूर्येन्दुयोगे[२१] चक्रार्धे व्यतीपातोऽथ वैधृतः ।
चक्रे च[२२] मैत्रपर्यन्ते विज्ञेयः सार्पमस्तकः[२३] ॥ २९ ॥

---

[१] व्यत्ययोस्तमिते A; व्यत्ययोऽन्तःस्थिते D, P. [२] °भ्यस्ते हीयतेऽह्° A; °गोलैर्द्विर° B. [३] निशापिचीयते B; निशावचीयते D. [४] याम्ये गोले विपर्ययात् A; गोले याम्यविपर्ययः D, P. [५] °भ्यस्तो A. [६] मध्याभक्तिः C. [७] °मिन्दोर्मध्ये C. [८] रवेर्हृत्वा A. [९] स्फुटाभुक्तिर्नि° A; स्फुटभुक्तिर्नि° B. [१०] °सुभिर्भक्त्या A; °भिर्हृत्वा B; °त्रादिभिर्भक्ता C. [११] °कादिका A. [१२] गतागते A; गतागतम् B. [१३] गतगन्तव्यना·····A; °नाड्यः स्युः B. [१४] °र्लब्धास्थितयो A. [१५] गत्यन्तरेण नास्य स्युः A; गत्यन्तरेण ल° B. [१६] गत्वा B. [१७] गतागते A, B. [१८] बबाधितः A. [१९] पक्वे B. [२०] स्वरूपा° D. [२१] अर्केन्दु° D. [२२] चक्रेश A. [२३] सर्वम° A.

केन्द्रकोटिभुजामौर्वी[1] तत्फलर्णधनादयः ।
भास्करादवबोद्धव्या ग्रहाणां मन्दशीघ्रयोः ॥ ३० ॥
क्रमोत्क्रमभवां[2] जीवां[3] पदयोरोजयुग्मयोः ।
वृत्तान्तरेण संक्षुण्णां[4] हरेद् व्यासदलेन ताम्[5] ॥ ३१ ॥
लब्धमूने[6] क्षिपेद् वृत्ते शोध्यमभ्यधिके[7] फलम् ।
स्फुटवृत्तमन्यथा स्यान्मण्डूकप्लुतिवद्गतिः[8] ॥ ३२ ॥
मन्दोच्चफलचापार्धं प्राग्वन्मध्ये धनक्षयौ ।
कृत्वा शीघ्रोच्चतः शोध्यं शीघ्रकेन्द्रं तदुच्यते ॥ ३३ ॥
तस्माद् बाहुफलं हृत्वा व्यासार्धेन विभज्यते ।
कर्णेनाप्तस्य चापार्धं धनर्णे[9] मेषतौलितः ॥ ३४ ॥
शोधयित्वा ततो मन्दं बाहोः कृत्स्नं फलं ततः[10] ।
काष्ठितं[11] मध्यमे कुर्यात् स्फुटमध्यः स उच्यते ॥ ३५ ॥
शोधयित्वा[12] तु तं[13] शीघ्राच्छीघ्रन्यायागतं फलम् ।
चापितं[14] सकलं कुर्यात् स्फुटमध्ये स्फुटो भवेत् ॥ ३६ ॥
कुजार्कसुतसूरीणामेवं[15] कर्म विधीयते ।
बुधभार्गवयोश्चाथ[16] प्रक्रिया परिकीर्त्यते ॥ ३७ ॥
प्रागेव चलकेन्द्रस्य फलचापदलं[17] स्फुटम्[18] ।
व्यस्तं[19] स्वकीयमन्दोच्चे धनर्णे[20] परिकल्पयेत् ॥ ३८ ॥
तेन मन्देन यल्लब्धं सकलं तत् स्वमध्यमे ।
स्फुटमध्यश्चलोच्चेन[21] संस्कृतः स स्फुटो ग्रहः ॥ ३९ ॥
वर्तमानो ग्रहस्तुल्यः श्वस्तनेन यदा भवेत् ।
वक्रारम्भस्तदा तस्य निवृत्तिर्वाऽथ कीर्तिता ॥ ४० ॥

---

[1] केन्द्रे कोटि° P. [2] °त्क्रमभवा A, P. [3] जीवा P. [4] °क्षुण्णा P. [5] °ाः A, P. [6] °मूनो A. [7] °मप्यधि° P. [8] °वृत्तमथान्ये च मण्डूक° A. [9] धनर्णं D. [10] फलं तु तत् A; कृत्स्नफलंत° P. [11] काष्ठिका A. [12] पातयित्वा A. [13] कृतं B, P. [14] यापितं A. [15] कुजार्किशुक्रसूरीणां एवं B. [16] °श्चापि A, D. [17] फलं चाप° D, P. [18] स्मृतम् D. [19] व्यक्तं A, B; यस्तं P. [20] स्वकीये मन्दोच्चधनर्णे D, P. [21] स्फुटमध्यंचलो° C, D.

श्वस्तनेऽद्यतनाच्छुद्धे वक्रभोगः प्रकीर्तितः[१] ।
विपरीतविशेषोत्थश्चारभोगस्तयोः[२] स्फुटः ॥ ४१ ॥

इति लघुभास्करीये द्वितीयोऽध्यायः ।

[१] प्रकीर्त्यते A. [२] °षानश्चारभोगास्तयोः A; विपरीते विशे° P.

तृतीयोऽध्यायः

इष्टमण्डलमध्यस्थशङ्कुच्छायाग्रवृत्तयोः[1] ।
योगाभ्यां कृतमत्स्येन ज्ञेये याम्योत्तरे दिशौ ॥ १ ॥

समायां कौ दिशां[2] मध्ये[3] शङ्कोर्ज्ञातार्जवस्थितेः[4] ।
विषुवद्दिनमध्याह्नच्छायाया वर्गसंयुतात् ॥ २ ॥

शङ्कुवर्गाद्धि यन्मूलं तेन त्रिज्या विभज्यते ।
शङ्कुच्छायासमभ्यस्ता लम्बकाक्षगुणौ[5] फले[6] ॥ ३ ॥

राश्यन्तापक्रमैः कार्याः पूर्ववत्तच्चरासवः ।
पूर्वशुद्धाः क्रमात्ते स्युर्मेषगोवल्लकीभृताम्[7] ॥ ४ ॥

शून्याद्रिरसरूपाणि भूतरन्ध्रमुनीन्दवः[8] ।
पञ्चाग्निरन्ध्रशशिनो मेषादीनां निरक्षजाः ॥ ५ ॥

चरप्राणाः क्रमाच्छोध्या दीयन्ते व्युत्क्रमेण[9] ते ।
स्वदेशभोदया[10] मेषाद् व्यत्ययेन तुलादितः ॥ ६ ॥

गतगन्तव्यघटिका दिनपूर्वापरार्धजाः ।
षष्ट्याऽभ्यस्ताः पुनः षड्भिः प्राणास्तेभ्यश्चरासवः ॥ ७ ॥

उदग्गोले विशोध्यन्ते[11] क्षिप्यन्ते दक्षिणे तु ते[12] ।
तेषां जीवा समभ्यस्ता[13] स्वाहोरात्रदलेन[14] सा[15] ॥ ८ ॥

व्यासार्धाप्तफले[16] कुर्याद् भूज्यां तस्य विपर्ययात् ।
लम्बकेन पुनर्हृत्वा त्रिज्यया शङ्कुराप्यते ॥ ९ ॥

तद्वर्गव्यासकृत्योर्यद्[17] विश्लेषान्तरजं[18] पदम् ।
छाया सा[19] द्वादशाभ्यस्ता[20] शङ्कुभक्ता प्रभा स्फुटा ॥ १० ॥

---

[1] इषुमण्डल° A; °मध्यस्थः° P. [2] समायान्तौ दिशोः A; ° दिशौ D. [3] मध्य A. [4] शङ्कोर्जातार्जवस्तथा A; शङ्कोर्जाताज्जव° P. [5] °गुणे A, B; °गुणो P. [6] फलम् P. [7] °गोवलतद्भुताः A; °मेंषकोवल्लकीभृता D. [8] भूतरन्ध्र मु° P. [9] व्यत्ययेन A. [10] °शजोयया A; °शभोदयो D. [11] °गोलेऽपिशा° A. [12] तु तत् A; कृते D. [13] समाभ्यस्ता B. [14] साहोरात्र° P. [15] सः A. [16] °सार्धेन फले P. [17] °कृत्योस्तु P. [18] °न्तरजा A. [19] छायाया A; च्छायासा B. [20] द्वादशा° B.

इष्टासुभ्यश्चराशुद्धौ[1] व्यत्ययः शेषजीवया[2] ।
शर्वर्यां शङ्कुरर्कस्य कार्यो व्यस्तेन[3] कर्मणा ॥ ११ ॥

शङ्कुच्छायाकृतियुतेर्मूलच्छेदेन[4] संहरेत् ।
त्रिमौर्वी[5] शङ्कुनाऽभ्यस्तां[6] शङ्कुस्तद्व्यत्ययाद् घटीः[7] ॥ १२ ॥

व्यासार्धसङ्गुणः शङ्कुर्लम्बकेन समुद्धृतः[8] ।
लब्धे क्षयोदया[9] भानौ क्षितिज्या[10] सौम्यदक्षिणे ॥ १३ ॥

व्यासार्धनिहते भूयः[11] स्वाहोरात्रार्धभाजिते ।
लब्धचापे[12] चरप्राणा देयाः शोध्याश्च गोलयोः ॥ १४ ॥

सौम्यदक्षिणयोः षड्भिः षष्ट्या भूयश्च नाडिकाः ।
गतगन्तव्यजा ज्ञेया दिनपूर्वापरार्धजाः ॥ १५॥

अक्षजीवाहतः शङ्कुर्लम्बकेन समुद्धृतः[13] ।
अस्तोदयाग्ररेखायाः[14] शङ्क्वग्रं नित्यदक्षिणम् ॥ १६ ॥

स्वदेशोदयसंक्षुण्णं राशिशेषं विवस्वतः ।
राशिलिप्ताहृतं[15] लब्धमिष्टासुभ्यो विशोधयेत् ॥ १७ ॥

राशिशेषं रवौ क्षिप्त्वा शेषासुभ्योऽपि यावताम्[16] ।
प्राणा विशुद्धास्तावन्तो दातव्या राशयः क्रमात् ॥ १८ ॥

त्रिंशदादिगुणे[17] शेषे वर्तमानोदयोद्धृते[18] ।
लब्धांशलिप्तिकायुक्तं प्राग्विलग्नं[19] विनिर्दिशेत् ॥ १९ ॥

प्राग्विलग्नगतान्प्राणान्संपिण्डय[20] व्युत्क्रमाद्रवेः ।
अभुक्तांशावधेः कालः[21] कल्प्यते[22] कालकाङ्क्षिणा[23] ॥ २० ॥

---

[1] °श्चराशुद्धा A. [2] °त्ययाच्छेष° A, B. [3] व्यत्यस्त A. [4] °मूलं'छेदेन A; °कृति युक्तेमूल° D; °च्छायागतियुते मूलच्छेदं न P. [5] त्रिमौर्वी A. [6] °भ्यस्तां is missing from D. [7] °घटीम् B; °घटी C, D, P. [8] °द्धृते A. [9] °दयौ B, C; लब्धेऽक्षयोदयो D; °दये P. [10] °ज्यां A. [11] भूयात् A. [12] लब्धं चापे P. [13] विभाजितः P. [14] °रेखायां A. [15] राशिलिप्ताच्छृतं P. [16] यावता A, C. [17] त्रिंशतादि° A; विंशदादिगुणे D. [18] °दयाहृते A, C, D; वर्तमानोदयादृते B. [19] प्राविलग्नं B. [20] °लग्नागतान्प्राणान् संविन्द्याद् A. [21] कालात् A. [22] कल्यते P. [23] काङ्क्षिणः A.

क्षुण्णां[1] परमया[2] क्रान्त्या भुजज्यामुष्णदीधितेः ।
लम्बकेन विभज्याप्तामर्काग्रां तां[3] प्रचक्षते ॥ २१ ॥
पलज्योनामुदक्क्रान्तिं[4] विष्कम्भार्धहतां हरेत् ।
समपूर्वापरः शङ्कुर्लब्धोऽर्कस्य[5] पलज्यया[6] ॥ २२ ॥
शङ्कुवर्गविहीनाया[7] विष्कम्भार्धकृतेः पदम् ।
द्वादशाभिहतं[8] भक्तं[9] शङ्कुना लभ्यते प्रभा ॥ २३ ॥
छायाविधानसम्प्राप्तः शङ्कुः क्षुण्णः[10] पलज्यया[11] ।
क्रान्त्या परमया भक्तो[12] लब्धजीवाकलाधनुः[13] ॥ २४ ॥
तिग्मांशुर्मण्डलार्धाच्च[14] परिशुद्धो[15] विधीयते[16] ।
सममण्डलदिङ्मार्गशङ्कुच्छायाप्रसाधितः ॥ २५ ॥
पिण्डतः[17] प्रविशुद्धानां ज्यानां सङ्ख्या[18] समाहता[19] ।
तिथिवर्गेण शेषं च स्वान्त्यज्याप्तयुतं[20] धनुः ॥ २६ ॥
पलापक्रान्तिचापानां[21] योगविश्लेषजो गुणः ।
छाया याम्योत्तरे भानौ नभसो मध्यसंस्थितेः[22] ॥ २७ ॥
तच्छायावर्गहीनस्य[23] त्रिज्यावर्गस्य[24] यत्पदम् ।
शङ्कुर्द्वादशसङ्ख्यस्य[25] छाया ज्ञेयाऽनुपाततः ॥ २८ ॥
शङ्कुवर्गेण युक्ताया मध्यच्छायाकृतेः पदम् ।
छेदस्त्रिराशिजीवायाश्छायाघ्नायाः[26] फलं नतिः[27] ॥ २९ ॥
नतभागाः[28] पलान्यूनाः[29] पलाच्छोध्या[30] रवेरुदक्[31] ।
दक्षिणेन यदा छाया योगः क्रान्तेर्धनुस्तदा ॥ ३० ॥

---

[1] क्षुण्णं A, P. [2] चरमया D. [3] °ज्याप्तमर्काग्रान्ता A; °मर्काग्रेति C. [4] पलज्योनमुदक्क्रान्ति A; फलज्योनामदक्क्रान्ति P. [5] समपूर्वापराशङ्कु° A. [6] फलज्यया P. [7] शङ्कुवर्गविहीनयां P. [8] द्वादशात्रिहतं P. [9] लब्धं A. [10] °सम्प्राप्तं शङ्कुं क्षुण्णं A; च्छाया° B, D. [11] फलज्यया P. [12] भक्ता A. [13] लब्धं जीव° C; लब्धजीवकला° P. [14] तिग्मांशोर्मण्डलार्धाञ्च A; तिग्मांशुमण्डलार्धाच्च B, C, D. [15] परिशुद्धा A. [16] भिधीयते A; ऽभिधीयते B, C, D. [17] पिण्डितः B. [18] सख्या A; यत्ता B, P. [19] समाहतः A. [20] स्वान्त्यज्याप्तहतं P. [21] °न्तिभागानां A, B, C. [22] °संस्थितौ B. [23] तद्वर्गहीनसङ्ख्यस्य D. [24] स्य is missing from B. [25] शङ्कोर्द्वा° P. [26] छेदास्त्रिराशिजीवायाश्चानेयाः A; च्छेदस्त्रिराशिजीवायां च्छायायां B; च्छेद° D. [27] फलतोन्नति A. [28] नतभाग D. [29] फलन्यूनाः A; पलान्यूनाः D. [30] फलाच्छोध्या A, B. [31] खावुदक C, D.

विपर्यये पलं[1] शोध्यं नतभागसमूहतः ।
अपक्रमधनुः शेषो दक्षिणेन विवस्वतः ॥ ३१ ॥

तज्जीवा त्रिज्ययाऽभ्यस्ता क्रान्त्या परमया हृता ।
लब्धचापो रविर्ज्ञेयश्चक्रार्धाच्च[2] विशोधितः ॥ ३२ ॥

उदग्गोले विधिर्ज्ञेयो दक्षिणे चोच्यते क्रमः[3] ।
चक्रार्धसहितं चापं द्वादशभ्यश्च पातितम्[4] ॥ ३३ ॥

शङ्कोर्याम्योत्तरस्थायां[5] नत्यक्षधनुषोः क्रमात् ।
छायायां योगविश्लेषौ[6] क्रान्तिकार्मुकसंज्ञितौ[7] ॥ ३४ ॥

नतापक्रान्तिभागानां[8] योगो भानावुदक्स्थिते ।
विश्लेषो व्यत्यये[9] कार्यश्छायायां[10] च पलं[11] भवेत् ॥ ३५ ॥

इति लघुभास्करीये तृतीयोऽध्यायः ।

---

[1] फल A, B. [2] °कार्धश्च C. [3] क्रमात् C, D. [4] द्वादशाभ्यस्तपा° C, P. [5] °स्थाया A; कार्या याम्योत्तरस्थाया D. [6] छायायामपविक्षेपौ A; च्छायाया यो° D. [7] नतिकार्मुकसंज्ञितम् A; कोटिकार्मुक° D. [8] नत्वप° A; नत्याप° C. [9] विगतौ व्यत्ययं A. [10] कार्यं छायायाः A; कार्यं च्छायायां B. [11] फलं C, D, P.

चतुर्थोऽध्यायः

पर्वनाड्यो[1] रवौ देयास्ताः सलिप्ता[2] निशाकरे ।
एवं प्रतिपदः शोध्याः समलिप्तादिदृक्क्षुणा[3] ॥ १ ॥

पञ्चवस्विषुरन्ध्रेषुसागरास्तिग्मतेजसः[4] ।
कर्णः[5] पर्वतशैलाग्निवेदरामा निशाकृतः ॥ २ ॥

अविशेषकलाकर्णताडितौ[6] त्रिज्यया हृतौ[7] ।
स्फुटयोजनकर्णौ तौ तयोरेव यथाक्रमम् ॥ ३ ॥

पङ्क्तिसागरवेदाख्यो रवेस्तिथिशिखीन्दुजः[8] ।
व्यासो वसुन्धरायाश्च व्योमभूतदिशः स्मृतः[9] ॥ ४ ॥

योजनव्याससंक्षुण्णं विष्कम्भार्धं विभाजयेत् ।
स्फुटयोजनकर्णाभ्यां लिप्ताव्यासौ[10] स्फुटौ तयोः[11] ॥ ५ ॥

कर्णः[12] क्षुण्णः सहस्रांशोर्मेदिनीव्यासयोजनैः ।
मेदिन्यर्कविशेषेण[13] भूच्छायादैर्घ्यमाप्यते ॥ ६ ॥

चन्द्रकर्णविहीनेऽस्मिन् भूमिव्यासेन ताडिते ।
छायादैर्घ्यहृते व्यासश्चन्द्रवत्तमसः कलाः ॥ ७ ॥

पातोनसमलिप्तेन्दोर्जीवा खत्रिघनाहता[14] ।
कर्णेन[15] हृियते लब्धो विक्षेपः सौम्यदक्षिणः ॥ ८ ॥

इन्दुहीनतमोव्यासदललिप्ताविवर्जिताः ।
विक्षेपस्य[16] न गृह्यन्ते तमसा शशलक्ष्मणः[17] ॥ ९ ॥

विक्षेपवर्गहीनायाः सम्पर्कार्धकृतेः[18] पदम् ।
गत्यन्तरहृतं हृत्वा षष्टया[19] स्थित्यर्धनाडिकाः ॥ १० ॥

---

[1] पर्वनाड्या A. [2] देयास्समलिप्ता A. [3] °लिप्तादि° D. [4] पञ्चवस्विष्ट-रन्ध्रेष्ट साग° A. [5] कर्ण B. [6] °ताडिताः A. [7] हृतः A. [8] °न्दुजाः A; °शिखी-षुजः C; [तिथिशिखीन्दुजः = तिथिशिखि (without case-ending) + इन्दुजः] [9] स्मृताः A. [10] लिप्तव्या° A. [11] तयोः स्फुटौ A, C, P; स्फुटा तयोः D. [12] कर्ण A. [13] मेदिन्यार्क° A. [14] वत्रिघना° A. [15] In place of कर्णेन the commentator Parameśvara refers to the reading व्यासेन° [16] क्षेपलिप्ता A. [17] °लक्षणः B. [18] सवर्गार्ध° A. [19] षष्ट्या हृत्वा A.

स्फुटभुक्तिहता[1] नाड्यः षष्ट्या नित्यं समुद्धृताः ।
लब्धलिप्ताः क्षयश्चन्द्रे क्षेपश्च स्पर्शमोक्षयोः ॥ ११ ॥
विक्षेपश्चन्द्रतस्तस्माच्चाडिका[2] लिप्तिकाः[3] शशी ।
आवृत्या कर्मणा तेन[4] स्थित्यर्धमविशेषयेत् ॥ १२ ॥
स्थित्यर्धेनाविशिष्टेन[5] हीनयुक्ता[6] तिथिः स्फुटा[7] ।
स्पर्शमोक्षौ तु तौ[8] स्यातां पर्वमध्यं[9] ग्रहस्य[10] तत्[11] ॥१३॥
ग्राह्यग्राहकविश्लेषदलविक्षेपवर्गयोः ।
विश्लेषस्य[12] पदं[13] प्राग्वद् विमर्दार्धस्य नाडिकाः ॥ १४ ॥
तिथिमध्यान्तरालानामसूनामुत्क्रमज्यया ।
विषुवज्ज्या हता[14] भाज्या[15] त्रिमौर्व्या लब्धदिक्क्रमः[16] ॥ १५ ॥
प्राक्कपाले तु बिम्बस्य पूर्वपश्चिमभागयोः ।
उदग्दक्षिणतोऽक्षस्य[17] वलनं पश्चिमेऽन्यथा ॥ १६ ॥
तत्कालेन्द्वर्कयोः कोट्योरुत्क्रमज्यापमो[18] गुणः ।
अयनाद्विम्बपूर्वार्धे पश्चार्धे व्यत्ययेन दिक् ॥ १७ ॥
योगस्तद्धनुषोः साम्ये दिशोर्भेदे[19] विपर्ययः ।
सम्पर्कार्धहता तज्ज्या[20] त्रिज्याप्तं वलनं हि तत् ॥ १८ ॥
एकदिक्कं[21] क्षिपेत् क्षेपे विदिक्कं[22] तद्विशोधयेत् ।
वलनं तत् स्फुटं ज्ञेयं सूर्याचन्द्रमसोर्ग्रहे ॥ १९ ॥
सम्पर्कार्धाधिकं[23] तद्धि सङ्ख्यया यत्र लभ्यते[24] ।
सम्पर्कात् सकलाद्धित्वा[25] वलनं तत्र शिष्यते[26] ॥ २० ॥

---

[1] स्फुटभुक्त्या हता P. [2] °न्द्रजस्त° P. [3] लिप्तिका B,C. [4] आवृत्तिकर्मणा येन A; आवृत्तिकर्मणानेन D; आवृत्त्या कर्मणानेन P. [5] °त्यर्धेनाविशि° B; °र्धेन विशिष्टेन P. [6] हीना युक्ता B, C. [7] स्थितिस्फुटः A; तिथि स्फुटा C. [8] ततः A, B. [9] पर्वमध्याद् A; °मध्य B. [10] गतस्य C. [11] च A. [12] विक्षेपस्य A, B. [13] पदात् A. [14] विक्षेपज्याहता A. [15] भज्या A; हाज्या B. [16] °दिक्क्रमात् A. [17] °दक्षिण-कोष्ठस्य D. [18] °ज्यावमो A; °योर्व्युत्क्रमज्यावमो C; °रुत्क्रमज्योपमो गुणः D. [19] दिशोभेदे A, C, P. [20] त्रिज्या B. [21] एकदिक्स्थां A; एतद्दिक्कं B. [22] विदिक्स्थं A; विदितं B. [23] सम्पर्काधिकं C. [24] लक्ष्यते A, C. [25] सकलं हित्वा A. [26] निर्दिशेत् A, B, C, D.

असंयुक्तमविश्लिष्टं[1] स्पर्शवत् केवलं स्फुटम् ।
विक्षिप्त्या[2] ग्रहमध्यस्य[3] तस्य स्याद् व्यस्तदिक्क्रमः[4] ॥ २१ ॥
भास्करेन्दुतमोव्यासविक्षेपवलनोद्भवाः[5] ।
अङ्गुलान्यर्धिता[6] लिप्तास्ता एव हरिजस्थिते[7] ॥ २२ ॥
ग्राह्याङ्गुलार्धविस्तृत्या वृत्तं सूत्रेण लिख्यते ।
ग्राह्यग्राहकसम्पर्कदलसङ्ख्येन चापरम् ॥ २३ ॥
पूर्वापरायतं सूत्रं[8] तन्मत्स्यात्[9] सौम्यदक्षिणम्[10] ।
कृत्वा यथादिशं केन्द्राद्बलनं नीयते स्फुटम् ॥ २४ ॥
विन्यस्तमत्स्यमध्येन[11] सूत्रं पूर्वापरे दिशौ ।
नीत्वा तु बाह्यवृत्तान्तं ततः केन्द्रं समानयेत् ॥ २५ ॥
ग्राह्यमण्डलतद्योगो[12] व्यक्तं यत्रोपलक्ष्यते ।
प्रग्रासग्रहमोक्षौ[13] स्तस्तत्र[14] देशे[15] निशाकृतः ॥ २६ ॥
तुल्यदिग्वलनक्षिप्त्योर्वलनं[16] बारुणीं नयेत्[17] ।
अन्यथैन्द्रीं[18] रवेर्व्यस्तं सूत्रं तन्मत्स्यतो[19] बहिः[20] ॥ २७ ॥
विक्षेपस्य वशात् केन्द्रमानयेत्[21] तत् यथादिशम् ।
विक्षेपं केन्द्रतो नीत्वा विन्दुं तत्र प्रकल्पयेत् ॥ २८ ॥
ग्राहकाङ्गुलविष्कम्भदलसङ्ख्येन[22] खण्डयेत् ।
ग्राह्यबिम्बं तथा मध्ये[23] ग्राहकस्यावतिष्ठते[24] ॥ २९ ॥
प्रग्रासमध्यमोक्षाणां बिन्दूनां[25] मस्तकानुगम् ।
मत्स्यद्वयोत्थवृत्तं यद् वर्त्म स्यात् ग्राहकस्य तत्[26] ॥ ३० ॥
स्थित्यर्धेनेष्टहीनेन हृत्वा गत्यन्तरं हरेत् ।
षष्टया लब्धकृतिं युक्त्वा विक्षेपस्य कृतेः पदम् ॥ ३१ ॥

---

[1] °विश्लिष्ट D. [2] विक्षिप्य P. [3] ग्रहमध्यः स्याद् A. [4] व्यस्तस्तस्यास्तु दिक्क्रमः A, C; तस्य स्याद्व्यस्तदिक्क्रमः P. [5] °बलनोद्भवात् A. [6] °न्यर्धितं A. [7] लिप्तास्तायेव हरिति स्थिते A; °स्थितेः D, P. [8] तत्र P. [9] तन्मध्ये A; तन्मध्यात् B, C, D. [10] दक्षिणोत्तरम् A, D. [11] विन्यस्तमध्यमध्येन C; विन्यस्यमत्स्य° P. [12] °तद्योगे C. [13] प्रग्राहग्रह° A; प्रग्रासाद् ग्रह° P. [14] स्तांतत्र A. [15] शे is missing from B. [16] °लनाक्षि° A; ° नक्षित्योवलंनं P. [17] नये is missing from B. [18] अन्य is missing from B. [19] तस्मा B. [20] बहिः is missing from B. [21] केन्द्रानानयेत् A. [22] °काङ्गुलिवि° A. [23] मत्स्ये D. [24] °कस्तावदिष्यते A. [25] बिन्दूनं A. [26] वर्त्मं तद् ग्राहकस्य तु A, D.

तन्नयेत् केन्द्रतो वर्त्म[1] यत्र सम्यक् तयोर्युतिः ।
तत्रेष्टकालजो ग्रासो ग्राहकार्धेन लिख्यते ॥ ३२ ॥

इति लघुभास्करीये चतुर्थोऽध्यायः ।

[1] तन्न चेत्केन्द्रतो वर्त्मा A.

पञ्चमोऽध्यायः

लम्बकाभिहता[1] त्रिज्या परमक्रान्तिसंहृता[2]।
लब्धं[3] स्वदेशसम्भूतो[4] व्यवच्छेदः प्रकीर्तितः ॥ १ ॥
लङ्कोदयानुपाताप्तानवगम्य रवेरसून् ।
तिथिमध्यान्तरासुभ्यो हित्वा शोध्यं गतं[5] ततः ॥ २ ॥
शेषेऽपि[6] यावतां सन्ति व्युत्क्रमात् तावतस्त्यजेत् ।
भागा[7] लिप्ताश्च पूर्वाह्णे मध्यलग्नमुदाहृतम् ॥ ३ ॥
अपराह्णे चयः कार्यो गन्तव्यादेर्विवस्वतः ।
पातहीनात्ततः कल्प्यो[8] विक्षेपः सौम्यदक्षिणः ॥ ४ ॥
मध्यलग्नापमक्षेपपलज्याधनुषां[9] युतिः ।
तुल्यदिक्त्वे विदिक्कानां[10] विश्लेषश्शेषदिग्वशात्[11] ॥ ५ ॥
मध्यजीवा तया क्षुण्णां[12] प्राग्विलग्नभुजां[13] हरेत् ।
व्यवच्छेदेन यल्लब्धं वर्गीकृत्य विशोधयेत् ॥ ६ ॥
मध्यज्यावर्गतः शेषो वर्गो दृक्षेपसंभवः ।
तत्कालशङ्कुवर्गेण युक्त्वा तं प्रविशोधयेत् ॥ ७ ॥
विष्कम्भार्धकृतेर्मूलं रूपरन्ध्रनिशाकरैः ।
हृत्वा लब्धस्य भूयोंऽशो[14] विज्ञेयो योऽर्धपञ्चमैः ॥ ८ ॥
लम्बनाख्यो[15] भवेत्कालो नाडिकाद्यो[16] रवेर्ग्रहे ।
पर्वणः शोध्यते प्राह्णे[17] दीयते मध्यतोऽपरे[18] ॥ ९ ॥
एवं कृतेन भूयोऽपि पर्वणा[19] कर्म कल्प्यते[20] ।
कालस्य लम्बनाख्यस्य निश्चलत्वं दिदृक्षुणा[21] ॥ १० ॥

---

[1] °हत A; लम्बकेन हता C. [2] °न्तिताडिता A; °संहता P. [3] लब्धः D, P. [4] स्वदेशजो भूमेः P. [5] नतं C. [6] शेषोऽपि A. [7] भाग B, C, D. [8] कार्यो A. [9] °लग्नावमक्षेपवलज्या° A, C; °क्षेपफलज्या° D; °लग्नावमक्षेप° P. [10] °दिक्च विदिक्स्थानां A; °दिक्के विदिक्कानां B. [11] विश्लेषश्लेषदिग्व° P. [12] मध्यजीवायतक्षु° P. [13] प्राग्वल्लग्न° A. [14] भूतांशो A. [15] लम्बनाड्यो A. [16] नाडिकाभ्यो A. [17] प्राह्णो A. [18] मध्यतः परे A. [19] पर्वणः A. [20] कथ्यते D. [21] निश्चलत्वं दि° B; निश्चलत्व दि° P.

दृक्क्षेपज्यामविश्लिष्टां गत्यन्तरहतां हरेत् ।
खस्वरेष्वेकभूताख्यैर्लब्धास्ता[1] लिप्तिकादयः ॥ ११ ॥
तत्कालशशिविक्षेपसंयुक्तास्तुल्यदिग्गताः ।
भिन्नदिक्का विशेष्यन्ते[3] रवेरवनतिः स्फुटा ॥ १२ ॥
अर्केन्दुबिम्बसम्पर्कदलादवनतेः[4] स्फुटात्[5] ।
स्थित्यर्धनाडिका साध्या प्राग्वद् वलनकर्म[6] च ॥ १३ ॥
प्रग्रासमोक्षयोरेवं लम्बनावनती सकृत्[7] ।
लम्बनान्तरसंयुक्ते[8] स्थित्यर्धे निर्दिशेत् स्फुटे ॥ १४ ॥
सम्पर्कार्धकलातुल्यकलासङ्ख्यानतौ[9] शशी ।
न रुणद्धि[10] रवेर्बिम्बं[11] ध्वान्तविध्वंसदीधितेः[12] ॥ १५ ॥

इति लघुभास्करीये पञ्चमोऽध्यायः ।

---

[1] विक्षेपजोमवि° A; विक्षेपज्यामवि° B; दिक्क्षेपज्या° [2] खस्वराद्र्येक° P. [3] विशोष्यन्ते A, C, D; विशिष्यन्ते P. [4] °दवनतेः A; °दलावनतितः B; °सम्पर्का-द्दलेनापनते D; °द्दलेनानवतेः P. [5] स्फुटाः B. [6] प्राग्व····लन° B; तथा वलन° D. [7] पृथक् A. [8] °संयुक्त A; र is missing from D. [9] °नते A; °संख्यनतौ D.P. [10] रुणद्धि हि A. [11] रवेर्बिम्बाद् P. [12] ध्वान्तविच्छ्वासदीधितेः A.

षष्ठोऽध्यायः

विक्षेपज्यां क्षपाभर्तुरक्षज्याक्षुण्णविग्रहाम्[1] ।
लम्बकेन हरेल्लब्धं विशोध्यं तत्स्फुटेन्दुतः ॥ १ ॥
उदये[2] सौम्यविक्षेपे देयमस्तमये[3] सदा[4] ।
व्यस्तं तद्याम्यविक्षेपे कार्यं[5] स्यादुदयास्तयोः[6] ॥ २ ॥
त्रिराश्यूनोत्क्रमक्षुण्णां तत्कालक्षिप्तिमाहताम्[7] ।
क्रान्त्या परमया भूयो हरेद् व्यासदलस्य ताम् ॥ ३ ॥
कृत्या लब्धकलाः शोध्या विक्षेपायनयोर्दिशोः[8] ।
तुल्ययोर्व्यत्ययेः[9] क्षेप्यं[10] शीतांशोस्तत्फलं[11] सदा ॥ ४ ॥
एवं कर्मक्रमात् सिद्धो दृश्यतेऽन्तरितः शशी ।
भागैर्द्वादशभिः सूर्याद् व्यभ्रे[12] नभसि निर्मले ॥ ५ ॥
अन्तरांशोत्क्रमां जीवां[13] स्फुटेन्दुव्यासताडिताम् ।
षण्णगाष्टरसैर्हृत्वा[14] सितमानं[15] पदाधिके ॥ ६ ॥
क्रमज्यामधिकोत्पन्नां त्रिज्यया योज्य तत् सितम् ।
आनयेदसितेऽप्येवमुत्क्रमक्रमतोऽसितम् ॥ ७ ॥
अन्तरालासुभिः कार्यश्चन्द्रभूज्याचरासुभिः[16] ।
शङ्कुः शङ्क्वग्रमप्यस्मात् साध्यते नित्यदक्षिणम् ॥ ८ ॥
विक्षेपक्रान्तिधनुषोर्भिन्नतुल्यस्वदिग्वशात्[17] ।
विश्लेषयोगजा जीवा सेन्दोः क्रान्तिस्ततः स्फुटा[18] ॥ ९ ॥

---

[1] क्षेपभक्तामक्षज्यांक्षुण्ण° A; °विग्रहम् C. [2] उभये A; उदय D. [3] उदयास्तमये D. [4] यदा B. [5] कार्यः A. [6] स्यादुभयास्तयोः B. [7] °क्षिप्तमा° B. [8] °पाननयो° A; °पायनयार्दिशोः D. [9] तुल्ययो व्यत्ययो D. [10] रक्षव्यं D; क्षेप्य P. [11] शीतांशौतत्फ° A, B. [12] तुर्याद्व्यभ्रे A; सूर्याद्व्यभ्रे B. [13] अनुरांशोत्क्रमा जीवा A; °त्क्रमाज्जीवां D, P. [14] षण्णवाष्ट° A; षण्णागाष्टनुसैर्हृत्वा D; षण्नगाष्ट° P. [15] सितमाना A; सितं मानं P. [16] कार्याश्च° A. [17] °तुल्यस्यदि° B. [18] क्रान्तिः स्फुटामता A, C, D, P.

स्वाहोरात्रादयः साध्या व्यासार्धाभिहतां[1] हरेत् ।
लम्बकेन शशिकान्तिमिन्द्वग्रं[2] तत्र[3] लभ्यते ॥ १० ॥

शङ्क्वग्रतुल्यदिक्त्वे[4] स्याद्युक्तं[5] विश्लिष्टमन्यथा[6] ।
अर्काग्रा तद्विशेषः स्यात्तुल्यदिक्त्वेऽन्यथा[7] युतिः ॥ ११ ॥

एवं सिद्धो भवेद् बाहुरर्कात् सम्यक्प्रसार्यते ।
कोटिसूत्रं तदग्रोत्थमत्स्यपुच्छास्यनिःसृतम्[8] ॥ १२ ॥

चन्द्रशङ्कुमिता[9] कोटिः[10] पूर्वतो[11] नीयते स्फुटम्[12] ।
तद्भुजामस्तकासक्तं कर्णसूत्रं विनिर्गतम् ॥ १३ ॥

कर्णकोटचग्रसम्पातकेन्द्रेणालिख्यते शशी ।
कर्णानुसारतस्तस्य[13] सितमन्तः प्रवेश्यते ॥ १४ ॥

कर्णः[14] पूर्वापरे काष्ठे तन्मत्स्याद्दक्षिणोत्तरे[15] ।
दक्षिणोत्तरयोर्विन्दू तृतीयः सितमानजः[16] ॥ १५ ॥

त्रिशर्कराविधानोत्थमत्स्यद्वयविनिःसृतम् ।
विन्दुत्रयशिरोग्राहिवर्त्मवृत्तं[17] समालिखेत् ॥ १६ ॥

वृत्तान्तरसितोद्भासिशृङ्गोन्नत्या[18] प्रदृश्यते[19] ।
ज्योत्स्नाप्रसरनिर्धूतध्वान्तराशिर्निशाकरः[20] ॥ १७ ॥

प्राक्कपाले[21] शशाङ्कस्य लग्नेन्द्वग्रादिभिः[22] स्फुटः[23] ।
साध्यो बाहुरनादिष्टमपराभिमुखं स्मृतम्[24] ॥ १८ ॥

मण्डलार्धयुतार्केन्दुविवरोत्पन्ननाडिकाः[25] ।
कृताविशेषकर्माणो दृश्यकालः[26] सिते स्फुटः[27] ॥ १९ ॥

---

[1] ब्या is missing from D; °सार्धान्निहतां P. [2] °मिन्द्वग्रा B. [3] चात्र A. [4] शङ्क्वग्रतुल्या दिक्त्वत्र A; °तुल्यदिक्के B. [5] युक्त A. [6] विशिष्ट° D. [7] °दिक्के ऽन्यथा B; तद्विशेष्या तुल्य° D. [8] °ग्रोत्थंम° B, P; °पुच्छस्यनिस्सृतः A. [9] चन्द्रशङ्कु-मतः A. [10] कोटि B. [11] पर्वतो B. [12] स्फुटा B. [13] °तस्तस्या A. [14] कर्णात् A; कर्ण B; कर्णं P. [15] तन्मध्याद्दक्षि° A; तन्मत्स्यात्सौम्यदक्षिणे C. [16] °योर्बिन्दु-स्तृतीयास्सितमानजाः A. [17] °पद्मवृत्तं B. [18] °न्तरे सितोद्भानि ग्रहोन्नत्या A. [19] प्रद-र्श्यते C. [20] °प्रवाहनि° A; °प्रकरनि° B; °प्रसारनि° C. [21] प्रोक्तपाले A. [22] लग्ने-न्द्वर्कादि° B; लग्नेन्द्वग्रादिति P. [23] स्फुटम् A, B, D; स्फुटा P. [24] स्फुटम् A. [25] °नालिकाः B. [26] °कालाः A, B; दृश्यकाले P. [27] स्फुटम् A, P.

अर्केन्दुसमलिप्तात्वे[1] पौर्णमास्यां समोदयः ।
प्रागेवाभ्युदितो हीनः पश्चादभ्यधिको रवे[2] ॥ २० ॥
ऊनाधिककलाक्षुण्णास्तद्ग्रहेष्टासवो[3] हृताः ।
राशिलिप्तासमूहेन लब्धः कालो[4] विशेषितः[5] ॥ २१ ॥
उदयेन्द्वन्तरप्राणैरस्तचन्द्रान्तरैरपि ।
स्वाहोरात्रादिभिश्चान्द्रैः शङ्कुदृग्ज्ये[6] ततः[7] प्रभा[8] ॥ २२ ॥
दिनान्तोदयलग्नस्य गन्तव्या[9] लिप्तिकाहताः[10] ।
स्वभोदयासुभिर्लब्धाः[11] प्राणराशिकलाहृताः[12] ॥ २३ ॥
सम्पिण्डच[13] शशिनो[14] यावद्भुक्तलिप्तावधेरिति[15] ।
स्फुटभोगानुपाताप्तमिन्दोः क्षिप्त्वाऽविशेषयेत्[16] ॥ २४ ॥
अविशिष्टेन कालेन शर्वर्यां दृश्यतेऽसिते[17] ।
विध्वस्तध्वान्तसंघातधामराशिर्निशाकरः[18] ॥ २५ ॥

इति लघुभास्करीये षष्ठोऽध्यायः ।

---

[1] °लिप्तत्वे B. [2] रविः A. [3] ऊनाधिक···लाक्षु° B; °स्तत्कालेष्टासवो C. [4] कार्यो D. [5] विशेषतः D. [6] शङ्कुं दृश्येत D.. [7] तत् D. [8] प्रभाः P. [9] शङ्कोर्वा A. [10] °हता A. [11] °लब्धा C. [12] प्राणाराशि° P. [13] संपिण्ड्याः P. [14] म्पिण्ड्यश is missing from D. [15] °भुक्तिलि° D. [16] °पाताप्तामिन्दोः कृत्वा क्षि° A; °मिन्दौ क्षि° C, P. [17] °ते शशी A; °ते सिते B, C, D, P. [18] °ध्वात···मराशि A.

सप्तमोऽध्यायः

कृतदर्शनसंस्कारो भार्गवोऽर्कान्तरस्थितैः[1] ।
अंशकैर्नवभिस्तेभ्यो[2] द्व्यधिकैर्द्व्यधिकैः[3] क्रमात् ॥ १ ॥
दृश्यन्ते सूरिवित्सौरिमाहेया[4] निर्मलेऽम्बरे[5] ।
कालभागा दिगभ्यस्ता विज्ञेयास्ता[6] विनाडिकाः ॥ २ ॥
राशेस्तस्यैव पूर्वस्यां[7] सप्तमस्यापरोदये ।
स्वदेशभोदयैः[8] कालं ज्ञात्वा दर्शनमादिशेत् ॥ ३ ॥
इष्टग्रहान्तरं भाज्यं प्रतिलोमानुलोमगम्[9] ।
भुक्तियोगविशेषेण दिनादिस्तत्र लभ्यते ॥ ४ ॥
स्फुटभुक्त्यानुपाताप्तफलेनासन्नयोगिनाम्[10] ।
ग्रहाणां शुद्धिकल्पाभ्यां[11] कुर्यात् समकलावुभौ ॥ ५ ॥
पातभागास्ततः शोध्याः शीघ्रोच्चात् सितसौम्ययोः ।
कृतद्व्यष्टर्तुककुभो दिग्गुणास्ते कुजादितः[12] ॥ ६ ॥
नवार्कर्त्वर्करवयो[13] दशघ्नाः क्षिप्तिलिप्तिकाः[14] ।
पातांशोनभुजामौर्वीसङ्गुणाः[15] सौम्यदक्षिणाः ॥ ७ ॥
विष्कम्भार्धहृतो घातो[16] मन्दशीघ्रोच्चकर्णयोः ।
भूताराग्रहविवरं भागहारः[17] प्रकीर्तितः[18] ॥ ८ ॥
विक्षेपलिप्तिका लब्धास्ताभिरन्तरमिष्टयोः[19] ।
एकदिक्त्वे[20] विशिष्टाभिर्युक्ताभिर्भिन्नदिक्कयोः[21] ॥ ९ ॥

---

[1] °स्थितः A. [2] °भिर्दृश्यो A. [3] द्व्यधिकैः is missing from D. [4] सूरिवत्सौरि° A,B,D. [5] निर्मलाम्बरे A, D. [6] °यास्ते C. [7] पूर्वस्याः A. [8] सन्देशभोदयैः A. [9] °नुलोमकम् C. [10] °क्त्यासपाताप्ताफले° A. [11] °कल्प्याभ्यां P. [12] कुजादिकाः B. [13] नवार्कचर्क° A; नवार्कत्वरवयो B. [14] क्षेपलिप्तिकाः A; क्षितिलिप्तिकाः B,P. [15] °मौर्वीसौगुणा B. [16] घातोः B. [17] °हाराः A. [18] °तिताः A. [19] लब्धास्माभि° C; लब्धास्ताराभि° D. [20] एकदिक्के B. [21] °भिन्नदिक्स्थयोः A.

चतुर्भागाङ्गुला[1] लिप्ता[2] ग्रहयोरन्तरं स्फुटम् ।
वर्णरश्मिप्रभायोगादूह्यमन्यत्[3] स्वया धिया ॥ १० ॥

इति लघुभास्करीये सप्तमोऽध्यायः ।

---

[1] °गाङ्गुले D. [2] लिप्तं A. [3] °दूह्यं वान्यत् B.

अष्टमोऽध्यायः[1]

अष्टावष्टादश दिशो[2] मनवोऽर्का[3] द्वयोर्घनः ।
द्वाविंशतिश्च विश्वे च नव शक्रास्त्रयोदश ॥ १ ॥
विश्वे विंशतिरेकोना[4] द्वादशार्का दिनानि च[5] ।
दिशो रसाश्च विश्वे च विश्वे सूर्या धृतिस्तथा ॥ २ ॥
रुद्राः सूर्यास्त्रिसप्ताथ शैलेन्दुतिथयस्तथा[6] ।
पूर्वपूर्वयुता[7] ज्ञेया योगभागा यथोदिताः ॥ ३ ॥
आप्यवैष्णवमूलानां[8] पित्र्यवासवयोरपि[9] ।
त्रिंशल्लिप्ताः सयाम्यानां क्षेप्या वैश्वस्य[10] शेषतः ॥ ४ ॥
योगभागसमः सर्वः संयुक्तो[11] लक्ष्यते ग्रहः ।
अधिकोनकलाकालविज्ञानं चानुपाततः ॥ ५ ॥
उदग्दिशोऽर्कभूतानि[12] याम्ये पञ्च दिशो[13] भवाः[14] ।
उदग्रसास्तथा व्योम दक्षिणे मुनयोऽम्बरम् ॥ ६ ॥
उदगर्कास्तथा विश्वे दक्षिणे मुनयोऽश्विनौ ।
सौम्ये रसकृतिः सैका याम्ये सार्धास्तथाग्नयः[15] ॥ ७ ॥
अब्धयो वसवः सार्धाः सप्तशैलास्ततः परम् ।
उदक् त्रिंशत् कृतिः षण्णां याम्ये लिप्तास्त्रिषट्ककाः ॥ ८ ॥
उदगर्काश्च विश्वे च द्विरभ्यस्ता नभस्तथा ।
विक्षेपांशाः क्रमाद् दृष्टाः पण्डितैर्वाजिभादितः ॥ ९ ॥
यावत्या[16] यद्दिशाक्षिप्त्या[17] यावांस्तारासमागमः[18] ।
तावत्या[19] तद्दिशाक्षिप्त्या[20] तावानिन्दुः समो[21] भवेत् ॥१०॥

---

[1] Missing from D. [2] दिशोः A; दिशा P. [3] मनवोक्ता A. [4] विंशतिरकोना B. [5] °शार्कास्त्रिपञ्चकाः A, C. [6] °तिथयः क्रमात् A, C. [7] पूर्वभागयुता A. [8] °वैणवमू° B. [9] विश्ववासव° A. [10] विश्वस्य A. [11] सम्यक्तो A. [12] उदग्दिगर्कभूतानि A, B. [13] याम्येऽपदिशो P. [14] द्भवाः B, C. [15] सार्धं तथाग्नयः A; °थानयः B. [16] यावन्त्या A. [17] यद्दिशाप्त्या A. [18] °समागमे B. [19] तावन्त्या A. [20] तद्दिशाक्षिप्या A. [21] °निन्दुसमो A.

अष्टिदंशगुणा लिप्ता विक्षेपस्य यदोत्तरे[1] ।
निरुणद्धि तदा[2] व्यक्तं[3] कृत्तिकातारकां शशी ॥ ११ ॥

उत्तरां परमां क्षिप्तिं गत्वा शिशिरदीधितिः ।
आवृणोति स्वबिम्बेन मघामध्यस्थतारकाम्[4] ॥ १२ ॥

आरोहति शशी षष्टया प्राजेशशकटं[5] स्फुटम् ।
अष्टिवर्गेण[6] याम्यायां योगतारा विलिख्यते ॥१३॥

याम्यगं[7] पञ्चहीनेन शतेन त्वाष्ट्रतारकम्[8] ।
मैत्रं शतेन सार्धेन द्विशत्या[9] शक्रतारकाम्[10] ॥ १४ ॥

सप्ताशीत्या शशी हन्ति तारां सौम्यविशाखयोः[11] ।
याम्यगो दक्षिणाशास्थो[12] व्यक्तं[13] शतभिषज्जिनैः[14] ॥ १५॥

पुष्यं पौष्णं च पातस्थो निरुणद्धि निशाकरः ।
यष्टियुक्तकलाक्षिप्त्या[15] भेदः स्याद् ग्रहधिष्ण्ययोः ॥ १६ ॥

शेषौ मण्डलजौ[16] यमक्षितिजयोः संयुक्तविश्लेषिता-
वन्योन्याहतविग्रहौ च पददौ[17] रूपेण संयोजितौ ।
एवं[18] साधु विचिन्त्य वर्गविधिना द्वित्रिक्रमाद्वत्सरैः[19]
संगण्या[20] द्युगणार्कजक्षितिसुताः[21] कालेन कालोद्भवाः॥ १७ ॥

लिप्ताशेषः कुजस्य द्विकघनगुणितो[22] मूलदो रूपयुक्तः
सप्ताभ्यस्तः सरूपः पुनरपि पददो[23]वर्गराशिः स एव ।
इत्थं शेषं विचिन्त्य क्षितिजदिनगणौ[24] वेत्ति यो वर्षपूगैः
स स्यादम्भोधिकाञ्च्यां गणितपटुधियामग्रगामी धरायाम् ॥ १८ ॥

---

[1] यदोत्तरम् A. [2] यदा A; तथा B. [3] व्यक्ति A. [4] मखामध्य° C. [5] प्तांजेशशकटं B. [6] अष्टवर्गेण A, P. [7] याम्यगः A; याम्याः B. [8] त्वाष्टितार° A; °तारकम् P. [9] विंशत्या A, C, P. [10] शक्रदैवतम्A; शाक्रसुप्रभाम् B; शक्रदेवताः P. [11] तारकां तु विशाख° P. [12] °णाशास्थौ A. [13] व्यक्तां A. [14] शाखाभिषज्जनैः A. [15] दृष्टियुक्त्याकला° A; दृष्टियुक्त° C, P. [16] मण्डलजो A. [17] पटदौ B. [18] इत्थं A, C. [19] °माद्वासरैः P. [20] संगुण्या B, P. [21] द्विगुणा° B; द्विगुणार्कजक्षितिसुतं P. [22] द्विघन° B. [23] पुनरखिलपदो B. [24] °नगणो B; °नगणान् C.

विस्तारग्रन्थभीरूणां ग्रहसद्वर्त्मवित्तये ।
निबन्धः कर्मणां प्रोक्तो भास्करेण समासतः ॥ १९ ॥[1]

इति लघुभास्करीये अष्टमोऽध्यायः ।

[1] This verse is missing from C.

लघुभास्करीये प्रयुक्तपारिभाषिक–

शब्दानाम् अनुक्रमणिका

अंश i. २२; iii. १९; vi. ६; vii. ७
अंशक vii. १.
अक्ष i. २५; iii. ३४; iv. १६
अक्षगुण iii. ३
अक्षजीवा iii. १६
अक्षज्या vi. १
अक्षस्य वलनम् iv. १६
अगत ii. १, २५, २७
अग्नि i. ४, ५, ७, ९, १२, १३, १४; ii. १६; iii. ५; iv. २; viii. ७
अग्र iii. १; vi. १०, १२, १४
अङ्क i. ९-११, १४
अङ्गुल iv. २२, २३, २९; vii. १०
अद्यतन ii. ४१
अद्रि i. ४, ९, १३, १४; iii. ५
अधिमास i. ६
अनुपात iii. २८; v. २; vi. २४; vii. ५; viii. ५
अनुलोम vii. ४
अनुलोमग vii. ४
अन्तराल iv. १५; vi. ८
अन्त्यज्या iii. २६
अन्त्यमौर्वी ii. ९
अपक्रम ii. १६; iii. ४
अपक्रमधनु iii. ३१
अपक्रान्ति iii. २७, ३५
अपक्रान्तिज्या iii. २७
अपक्रान्तिभाग iii. ३५
अपम ii. १६, १७; iv. १७; v. ५
अपमौ गुण iv. १७
अपर iv. २४; v. ९; vii. ३
अपरा iv. २५; vi. १५, १८
अपराह्न v. ४
अब्धि i. ५; viii. ८
अभुक्तांश iii. २०
अभ्यास i. १५; ii. १६
अमृततेजस् i. २२
अम्बर i. ७, १३; viii. ६
अम्भोधि i. १०
अयन iv. १७; vi. ४
अयुत i. ५, ९
अर्क i. ३७; ii. १६, २६; iii. ११, २१, २२; iv. ६, १७; v. १३; vi. ११, १२, १९, २०; vii. १, ७; viii. १, २, ६, ७, ९
अर्कज viii. १७
अर्कसुत ii. ३७
अर्काग्रा iii. २१; vi. ११
अर्कोदय i. १६
अर्धपञ्चम v. ८
अर्धरात्र ii. २०
अक्रान्ति v. १२-१४
अवमरात्र i. ८
अवशिष्ट iv. १३; vi. २५
अविशेषकर्म vi. १९
अविशेषकलाकर्ण iv. ३
अविशेषण ii. ७
अश्वि i. ७, १०, १२, १४, २४; ii. २७
अश्विन् viii. ७
अश्विनी ii. २५

अष्टि viii. ११
असित ii. २८; vi ७
असु iii. ११, १७, १८; iv. १५; v. २; vi. ८
अस्त i. ३५; ii. २०; vi. २, २२
अस्तमय vi. २
अस्तोदयाग्ररेखा iii. १६
अहन् ii. १५
अहर्गण i. ८, १५
अहोरात्र ii. १८; vi. १०, २२
अहोरात्रदल iii. ८
अहोरात्रासु ii. २३
अहोरात्रार्ध iii. १४
अहोरात्रार्ध-विष्कम्भ ii. १७
आदित्य ii. २४
आप्य viii. ४
आशा i. २८
इन्दु i. ५, ७,१४; ii. ११, १३, १४, २२, २४, २६; iii. ५; iv. ४, ८, ६, १७, २२; v. १३; vi. १, ६, ६, १०, १६, २०, २२, २४; viii. ३, १०
इन्दूच्च i. १२
इन्द्रग्र vi. १०, १८
इषु i. ७; iv. २; v. ११
इष्ट ii. १६, १७; iii. १, ११, १७ iv. ३१, ३२; vi. २१; vii. ४, ६
इष्टकाल iv. ३२
इष्टग्रह vii. ४
इष्टासु iii. ११, १७; vi. २१
उच्च ii. १
उत्क्रम ii. ११; vi. ३, ७
उत्क्रमजीवा vi. ६
उत्क्रमज्या iv. १५, १
उत्क्रमज्याफल iv. १५
उत्क्रमभवा जीवा ii. ३१
उत्तर iii. १; vi. १५; viii. ११, १२
उदक् iii. २२, ३०, ३५; iv. १६; viii. ६—६
उदग्गोल ii. २०, २१; iii. ८, ३३
उदय i. ८; ii. १३, २०, २६; iii. १३ vi. २, २०, २२; vii. ३
उपप्लुति i. ३०
उष्णदीधिति iii. २१
ऋतु vii. ६, ७
एकदिक्क iv. १६
ऐन्द्री iv. २७
ओज ii. २, ११, ३१
ककुभ vii. ६
करण ii. २८
कर्कट ii. १०
कर्ण i. २६, २७; ii. ६-८, ३४; iv. २, ६, ८; vi. १४, १५
कर्णभुक्ति ii. १५
कर्णसूत्र vi. १३
कला i. १५; ii. ११; iii. २४; iv. ७; v. १५; vi. ४, २१; viii. ५, १६
कल्प vii. ५
कार्मुक iii. ३४
काल i. २, २६, ३७; iii. २०; iv. १७; v. ७, ६, १०, १२; vi. १६, २१, २५; vii. ३; viii. ५, १७
कालभाग vii. २
काष्ठा vi. १५
कु iii. २
कुज i. १०, १८; ii. ३७; vii. ६; viii. १८
कृत vii. ६

कृति ii. १७; iii. १०, १२, २३, २९; iv. १०, ३१; v. ८; vi. ४
कृत्तिका viii. ११
केन्द्र ii. १, ४, १०, ३०; iv. २४, २५, २८, ३२; vi. १४
केन्द्रभुक्ति ii. ११, १२
कोटि ii. १, २, ३०; iv. १७; vi. १३, १४
कोटिफल ii. ३
कोटिसाधन ii. ६
कोटिसूत्र vi. १२
क्रम ii. ११; vi. ७
क्रमज्या vi. ७
क्रमभवा जीवा ii. ३१
क्रान्ति iii. २१, २२, २४, ३०, ३२, ३४; v. १; vi. ३, ९, १०
क्रिय ii. ४
क्षपाभर्तृ vi. १
क्षय ii. १३, २२, २४, ३३; iii. १३; iv. ११
क्षितिज viii. १७, १८
क्षितिज्या ii. १८; iii. १३
क्षितिसुत viii. १७
क्षिप्ति iv. २७; vi. ३; viii. १०, १२, १६
क्षिप्तिलिप्तिका: vii. ७
क्षेप iv. १९; v. ५
ख i. ७, १२; ii. १९; iv. ८; v. ११
गणित i. २९, ३०; viii. १८
गणित प्रक्रिया i. २९
गत ii. १, १२, २५-२७; iii. ७, १५, २०
गति i. १, ३, ३६; ii. ३२
गत्यन्तर iv. १०, ३१; v. ११
गन्तव्य ii. १२, २६; iii. ७, १५; v. ४; vi. २३
गुण ii. ११, १३, १६; iii. १९, २७; iv. १७; vii. ६; viii. ११
गुरु i. १०
गो iii. ४
गोल ii. २१; iii. ८, १४
ग्रह i. १७, ३५, ३६; ii. ३०, ३९, ४०; iv. १३, १९, २६; v. ९; vi. २१; vii. ५, १०; viii. ५, १६
ग्रहण i. २९
ग्रहमध्य iv. २१
ग्रहसद्वर्त्म viii. १९
ग्रास iv. ३२
ग्राहक iv. १४, २३, २९, ३०, ३२
ग्राहकार्ध iv. ३२
ग्राह्य iv. १४, २३, २९
ग्राह्यबिम्ब iv. २९
ग्राह्यमण्डल iv. २६
घटिका iii. ७
घटी iii. १२
घन ii. १९; viii. १८
घात vii. ८
चक्र i. १७; ii. २९
चक्रलिप्ता ii. ४, २२
चक्रार्ध i. १८; ii. २९; iii. ३२-३३
चक्रांशक i. २५
चन्द्र ii. २४; iv. ७, ११, १२; vi. ८, १३, २२
चन्द्रकर्ण iv. ७
चन्द्रमस् iv. १९
चन्द्रशङ्कु vi. १३
चर iii. ११
चरजीवार्ध ii. १८

चरप्राण ii. २३; iii. ६, १४
चरासु ii. २१; iii. ४, ७; vi. ८
चलकेन्द्र ii. ३८
चलकेन्द्रफल ii. ३८
चलोच्च ii. ३९
चाप ii. १९, ३३, ३४, ३८; iii. १४, २७, ३२, ३३
चापभाग ii. १४
चापित ii. ३६
चारभोग ii. ४१
चैत्र i. ४
छाया iii. १, ३, १०, १२, २५, २७–३०, ३४, ३५; iv. ६
छायादैर्घ्य iv. ७
छायाविधान iii. २४
छेद i. ७; iii. १२, २९
जलधि i. १९
जिन viii. १५
जीवा ii. २, १४; iii. ८, ११, २४, ३२; iv. ८; vi. ९
जीवाभुक्ति ii. १५
जूक ii. ४
ज्या iii. २६; iv. १८
ज्योतिस् i. १, ३
तम iv. ७; ९
तमोमूर्ति i. १७
तमोव्यास iv. २२
तमोव्यासदल iv. ९
तारका viii. १२, १४
तारासमागम viii. १०
तिग्मतेजस् iv. २
तिग्मरश्मि i. २८
तिग्मांशु ii. ५; iii. २५
तिथि i. ३४, ३६, ३७; ii. २७; iv. ४, १३, १५; v. २; viii. ३
तिथिवर्ग iii. २६
तिथ्यर्धहार ii. २८
तिर्यक् i. २६
तुला iii. ६
तुल्यत्व i. २८
तुल्यदिक् iv. २७; v. १२; vi. ९
तुल्यदिक्त्व v. ५; vi. ११
त्रिज्या ii. १६; iii. ३, ९, २८, ३२; iv. ३, १८; v. १; vi. ७
त्रिमौर्वी iii. १२; iv. १५
त्रिराशि vi. ३
त्रिराशिजीवा iii. २९
त्रिशर्करविधान vi. १६
त्रैराशिक ii. १२
त्वाष्ट्र viii. १४
दक्षिण iii. ८, १३, १५, १६, ३०, ३१, ३३; iv. ८, १६, २४; v. ४; vi. ८, १५; vii. ७; viii. ६, ७
दक्षिणाशा viii. १५
दर्शन-संस्कार vii. १
दल iv. २३
दस्र i. ९, १०, १३, १४, १८
दिक् iii. १, २; iv. १५, १७, २१; v. ५, १२; vi. ९; vii. २, ६; viii. ६
दिक्क v. १२; vii. ९
दिन vii. ४; viii. २
दिनगण viii. १८
दिनपूर्वापरार्ध iii. ७, १५
दिनान्तोदयलग्न vi. २३
दिनार्ध i. २८
दिश् iii. १, २; iv. ४, १८, २४, २५, २८; vi. ४; viii. १, २

दिशा viii. १०
दृक्क्षेप v. ७
दृक्क्षेपज्या v. ११
दृश्यकाल vi. १९
देशान्तर i. २३, २६, २९, ३१, ३२, ३४; ३७
देशान्तर-घटी i. ३१, ३२, ३४
द्युगण viii. १७
द्युचारिन् vi. ३१
द्रष्टा i. ३०
घन i. ३१, ३६, ३७; ii. ४, २२, २४, ३०, ३३, ३४, ३८
धनुः ii. १२; iii. २४, २६, ३०, ३४
धनुर्भाग ii. २
धनुस् ii. ३, ८; iv. १९; v. ५; vi. ९
धरा viii. १८
धिष्ण्य viii. १६
धृति viii. २
नग vi. ६
नतभाग iii. ३०, ३१, ३५
नति iii. २९; v. १५
नभ viii. ९
नभसोमध्य iii. २७
नाडिका i. ३५; iii. १५; iv. १०, १२, १४; v. ९, १३; vi. १९
नाडी ii. २६; iv. १, ११
निरक्षजा असवः iii. ५
निशा ii. २१
निशाकर i. १२; iv. १; v. ८; vi. १७, २५; viii. १६
निशाकृत् i. ९; ii. ५, २२, २३; iv. २, २६
निशानाथ ii. २५, २६
पक्ष ii. २८
पद ii. १, ११, १७, ३१; iii. १०, २३, २८, २९; iv. १०, १४, ३१; vi. ६; viii. १७, १८
पद्मिनीबन्धु ii. १
परमक्रान्ति iii. २१, २४, ३२; v. १; vi. ३
परमक्षिप्ति viii. १२
परमापक्रम ii. १६
परमापक्रमो गुणः ii. १६
परिधि i. २१, २२, २७; ii. ३
पर्यय i. १३, १५
पर्व iv. १; v. ९, १०
पर्वत ii. २७; iv. २
पर्वमध्य iv. १३
पर्वनाडी iv. १
पल i. २८; iii. २७, ३०, ३१, ३५
पलज्या ii. १७; iii. २२, २४; v. ५
पश्चार्ध iv. १७
पश्चिम i. ३०, ३१, ३५; iv. १६
पात i. १३; iv. ८; v. ४; vii. ६, ७; viii. १६
पातभाग vii. ६
पित्र्य viii. ४
पुष्कर i. ९
पुष्य viii. १६
पूर्व i. ३०; iv. १६, १७, २५; vi. १३, १५; viii. ३
पूर्वापरायतम् iv. २४
पूर्वाह्ण v. ३
पौर्णमासी vi. २०
पौष्ण viii. १६
पङ्क्ति iv. ४
प्रकृति i. १२
प्रक्षेप i. ३४

प्रक्रिया i. १, २९, ३६; ii. ३७
प्रग्रास iv. २६, ३०; v. १४
प्रतिपद् iv. १
प्रतिलोम vii. ४
प्रभा iii. १०, २३; vi. २२
प्राक्कपाल iv. १६; vi. १८
प्राग्विलग्न iii. १९, २०; v. ६
प्राची i. ३१, ३५
प्राजेशशकट viii. १३
प्राण ii. १९; iii. ७, १८, २०; vi. २२, २३
प्राह्ण v. ९
फल ii. ६, ७, १२, २३, २५, ३०, ३२, ३६, ३८; iii. ३, ९; vi. ४; vii. ५
बव ii. २८
बाहु i. २५, २६; ii. २, ६; vi. १२, १८
बाहुफल ii. ३४
बिन्दु iv. २८, ३०; vi. १५, १६
बिम्ब iv. १६, १७, २९; v. १३, १५; viii. १२
बुध i. १२; ii. ३७
भ iii. ६; vii. ३
भगण i. ११
भव viii. ६
भाग i. १५, १८; ii. ५, १४, १९; iv. १६; v. ३; vi. ५; vii. ६
भागहार i. ५, १६; vii. ८
भाज्य ii. २५; vii. ४
भानु i. ९; iii. १३, २७, ३५
भार्गव i. ११, १३; ii. ३७; vii. १
भास्कर i. १, ८, १३, १६, २२; ii. २४, ३०; iv. २२
भास्वत् ii. २२
भिन्नदिक् vi. ९
भिन्नदिक्क v. १२; vii. ९
भुक्त vi. २४
भुक्ति i. ३१, ३३; ii. ८, ९, ११, १४, २२, २७
भुक्तियोग vii. ४
भुक्तिविशेष vii. ४
भुक्त्यन्तर ii. २७
भुजज्या iii. २१
भुजा ii. १, २, १६, ३०; v. ६; vi. १३; vii. ७
भुजाफल ii. ३, ४, ५, २२
भुजामौर्वी vii. ७
भू i. २७, ३३; iv. ६
भूच्छायादैर्घ्य iv. ६
भूज्या iii. ९; vi. ८
भूत i. ५, ११; iii. ५; iv. ४; v. ११; viii. ६
भूताराग्रहविवर vii. ८
भूदिन i. १४, १५
भूमि i. २४, २५, ३२; iv. ७
भूमिव्यास iv. ७
भूमेः वृत्तम् i. २४, २५
भेद viii. १६
भोग i. ३४; ii. ४, १३
मकर ii. १०
मघा viii. १२
मघामध्यस्थतारकम् viii. १२
मण्डल iii. १; viii. १७
मण्डलमध्य iii. १
मण्डलार्ध iii. २५
मत्स्य iii. १; iv. २४, २५, ३०; vi. १२, १५, १६
मध्य i. १७, ३१; ii. ८, १३, २२, ३३;

iii. १; iv. १५, ३०; v. २, ६
मध्यच्छाया i. २८; iii. २६
मध्यजीवा v. ६
मध्यज्या v. ७
मध्यभुक्ति ii. १०
मध्यम i. १३, ३३; ii. १, ६, ३५; ३६
मध्यमा भुक्तिः i. ३३; ii. ६
मध्यलग्न v. ३, ५
मध्या भुक्तिः i. ३१; ii. ८, २२
मध्याह्न ii. २०
मध्याह्नच्छाया iii. २
मनु viii. १
मन्द i. १६, २२; ii. ३६
मन्दोच्च ii. ३८
मन्दोच्चकर्ण vii. ८
मन्दोच्चफल ii. ३३
मन्दांश i. २२
मास i. ४
मांहेय vii. २
मुनि iii. ५; viii. ६, ७
मूल i. २६; ii. ६; iii. ३, १२; v. ८; viii. ४, १८
मृग ii. ६
मेदिनी iv. ६
मेष ii. ३४; iii. ४-६
मैत्र ii. २६; viii. १४
मोक्ष iv. ११, १३, २६, ३०; v. १४
मौर्वी ii. ३०; vii. ७
यम i. १०, १३, १४; viii. १७
यमल i. १४
यात i. ६
याम्य ii. २०, २१; iii. १, २७; vi. २; viii. ४, ६, ७, ८, १३–१५
याम्योत्तर iii. २७, ३४
युगाधिक i. ४
युगावम i. ६
युग्म i. १६, २१; ii. २, ११, ३१
युति iv. ३२
योग iii. १, २७, ३०, ३४, ३५; iv. १८; vi. ६
योगतारा viii. १३
योगभाग viii. ३, ५
योजन i. ३२, ३३
योजनकर्ण iv. ३, ५
योजनव्यास iv. ५
रन्ध्र i. १२, १४, २४; ii. १६; iii. ५; iv. २; v. ८
रवि ii. १४, २२, २३; iii. १८, २०, ३०, ३२; iv. १, ४, २७; v. २, ६, १२, १५; vi. २०; vii. ७
रस i. ७, १०; iii. ५; vi. ६; viii. २, ६
राजपुत्र i. ११
राम i. ५, ६, १०; iv. २
राशि i. १५, १७; ii. १; iii. ४, १८; vii. ३
राशिकला vi. २३
राशित्रय ii. १
राशिशेष iii. १७, १८
रुद्र viii. ३
रूप ii. १६, २८; iii. ५; v. ८; viii. १७, १८
रेखा i. २३, ३१
लग्न vi. १८
लङ्का i. २३
लङ्कोदय v. २
लम्बक i. २४; ii. १८; iii. ६, १३, १६, २१; v. १; vi. १, १०

लम्बकगुण iii. ३
लम्बन i. ३७; v. ६, १०, १४
लिप्ता iv. १, ५, ६, ११, २२; v. ३; vi. २४; vii. १०; viii. ४, ८, १८
लिप्ताव्यास iv. ५
लिप्ताशेष viii. १८
लिप्तिका ii. ५, १६, २३; iii. १६; iv. १२; v. ११; vi. २३
वक्रत्व i. २७
वक्रभोग ii. ४१
वक्रारम्भ ii. ४०
वत्सर viii. १७
वर्ग i. २६; ii. ६, १७; iii. २, ३, १०, २८, २६; iv. १०, १४; v. ७; viii. १३, १७
वर्गविधि viii. १७
वर्गराशि viii. १८
वर्तमान ii. ३
वर्तमानगुण ii. ११
वर्तमानग्रह ii. ४०
वर्तमानोदय iii. १६
वर्त्म iv. ३०, ३२
वर्त्मवृत्त vi. १६
वर्ष viii. १८
वर्षपूग viii. १८
वलन iv. १६, १८-२०, २२, २४, २७
वलनकर्म v. १३
वल्लकीभृत् iii. ४
वसु i. ५, १०, १२, १३; iv. २
वसुन्धरा iv. ४
वह्नि i. २४
वार i. ८
वारुणी iv. २७
वासव viii. ४
विक्षिप्ति iv. २१
विक्षेप iv. ८-१०, १२, १४, २२, २८, ३१; v. ४, १२; vi. २, ४, ६; viii. ११
विक्षेपज्या vi. १
विक्षेपलिप्तिका vii. ६
विक्षेपांश viii. ६
वित् vii. २
विदिक्क iv. १६; v. ५
विधि i. ३४; ii. ७, ८; iii. ३३
विनाडिका vii. २
विमर्दार्ध iv. १४
वियत् i. ७
विलिप्ता i. १७
विलिप्तिका ii. ५
विवर vi. १६
विवस्वत् ii. २०; iii. १७, ३१; v. ४
विशाखा viii. १५
विश्लेष i. २५, २६, २६; ii. १५, १७; iii. १०, २७, ३४, ३५; iv. १४; v. ५; vi. ६
विश्व viii. १, २, ७, ६
विषुवज्या iv. १५
विषुवद्दिन iii. २
विषुवद्दिनमध्याह्नच्छाया iii. २
विष्कम्भदल iv. २६
विष्कम्भार्ध iii. २२, २३; iv. ५; v. ८; vii. ८
विस्तृति iv. २३
वृत्त i. २४, २५, ३२; ii. ६, १३, ३१, ३२; iii. १; iv. २३, ३०; vi. १७
वेद i. १०, ११; iv. २, ४
वैधृत ii. २६

वैश्व viii. ४
वैष्णव viii. ४
व्यतीपात ii. २९
व्यवच्छेद v. १, ६
व्यास ii. १७; iii. १०; iv. ४, ६, ७; vi. ६
व्यासदल ii. ३१; iv. ९; vi. ३
व्यासयोजन iv. ६
व्यासार्ध i. २४; ii. ६, ७, ८, १८, ३४; iii. ९, १३, १४; vi. १०
व्योम i. ७, १४; iv. ४; viii. ६
शकाब्द i. ४
शक्र viii. १
शक्रतारकम् viii. १४
शङ्कु iii. १-३, ९-१३, १६, २२–२५, २८, २९, ३४; v. ७; vi. ८, २२
शङ्क्वग्र iii. १६; vi. ८, ११
शतभिषक् viii. १५
शनि i. ११
शर i. ५, ७, ९, १४
शशलक्ष्मा iv. ९
शशाङ्क vi. १८
शशि iii. ५; iv. १२; v. १२, १५; vi. ५, १०, १४, २४; viii. ११, १३, १५
शश्युच्च i. १७
शिखि iv. ४
शिशिरदीधिति viii. १२
शीघ्र i. १३, २०; ii. ३०, ३६
शीघ्रकेन्द्र ii. ३३
शीघ्रभ्यायागतं फलम् ii. ३६
शीघ्रोच्च ii. ३३; vii. ६
शीघ्रोच्चकर्ण vii. ८
शीतांशु i. ३५; ii. ७, ८; vi. ४
शुक्र i. ८
शून्य i. ७, १४; ii. २७; iii. ५
श्रृङ्गोन्नति vi. १७
शेष i. ८, १५; ii. ३, २४; iii. ११, १७–१९, २६, ३१; v. ३, ७; viii. १७, १८
शैल i. ९, १२, १९; iv. २; viii. ३, ८
संयुक्त viii. ५
संस्कृत ii. ३९
सकृत् v. १४
सङ्ख्या i. २७; iii. २६; iv. २९; v. १५
समकल vii. ५
समपूर्वापर iii. २२
समपूर्वापरः शङ्कुः iii. २२
सममण्डल iii. २५
समरेखा i. २५, २६
समलिप्तेन्दु iv. ८
सम्पर्क iv. २०, २३
सम्पर्कदल iv. २३; v. १३
सम्पर्कार्ध iv. १०, १८, २०; v. १५
सहस्रांशु ii. ८, १०; iv. ६
सागर i. ९, १०, १२; iv. २, ४
सायक i. ९
सार्पमस्तक ii. २९
सावित्र i. ११
सित ii. २८; vi. ७, १४, १७ १९; vii. ६
सितपक्ष ii. २८
सितमान vi. ६, १५
सुराधिप i. ११, १९
सूरि ii. ३७; vii. २
सूर्य ii. २९; iv. १९; vi. ५; viii. २, ३

सौम्य iii. १३, १५; iv. ८, २४; v. ४; vi. २; vii. ६, ७; viii. ७
सौरि vii. २
स्थित्यर्ध iv. १०, १२, १३, ३१; v. १३, १४
स्थित्यर्धनाडिका iv. १०
स्थूल i. २७
स्पर्श iv. ११, १३, २१
स्फुट i. १, २; ii. १३, १५, १६, २४, ३६, ३८, ३९, ४१; iii. १०; iv. ३, ५, १३, १९, २१, २४; v. १२, १३, १४; vi. १, ६, ९, १३, १८, १९; vii. १०
स्फुटग्रह ii. ३९
स्फुटभुक्ति ii. ८, १०, १९, २३, २६; iv. ११; vii. ५
स्फुटभोग vi. २४
स्फुटमध्य ii. ३५, ३६, ३९
स्फुटयोजनकर्ण iv. ३, ५
स्फुटवृत्त ii. ३२
स्वदेशभूमिवृत्त i. ३२
स्वदेशभोदय iii. ६; vii. ३
स्वदेशाक्ष i. २५
स्वदेशोदय iii. १७
स्वभूवृत्त i. ३३
स्वर v. ११
हरिज iv. २२

लघुभास्करीये प्रयुक्त–

छन्दसाम् अनुक्रमणिका

अनुष्टुभ् (श्लोक) i. १–३७; ii. १–४१; iii. १–३५; iv. १–३२; v. १–१५; vi. १–२५; vii. १–१०; viii. १–१६, १९
शार्दूलविक्रीडित viii. १७
स्रग्धरा viii. १८

English Translation

OF THE

LAGHU – BHĀSKARĪYA

CHAPTER I

MEAN LONGITUDES OF THE PLANETS

Homage to the Sun :

1. I bow to the Sun—to Him with the help of whose motion this true motion of the heavenly bodies is inferred even though the methods (adopted for the purpose by different writers) be different.

Homage to Āryabhaṭa I :

2. Victorious is Āryabhaṭa whose excellent fame has crossed the bounds of the (Indian) oceans and whose (treatise on astronomical) science leads to accurate results in far off places (even) after the lapse of so much time.

Appreciation of Āryabhaṭa I and his work :

3. None except Āryabhaṭa has been able to know the motion of the heavenly bodies : there the others (merely) move in the ocean of utter darkness of ignorance (*ajñānabahaladhvāntasāgara*).

Śaṅkaranārāyaṇa reads *alaṁ* in place of *nālaṁ* and so he interprets the passage as follows : "Those who endeavour to determine the motion of the planets with the help of other astronomical works than the *Āryabhaṭīya* move in vain in the ocean of utter darkness of ignorance".

The compound word *ajñānabahaladhvāntasāgara* may also be interpreted to mean "the ocean of the darkness of utter ignorance".

By eulogizing Āryabhaṭa I and his work on mathematics and astronomy in the above stanzas the author has indicated the system of astronomy that he is going to follow in the present work.

A rule for calculating the *ahargaṇa* :

4-8. Add 3179 to the (number of elapsed) years of the Śaka era, (then) multiply (the resulting sum) by 12, and (then) add the (number of lunar) months (expired) since the com-

mencement of Caitra. Set down (the result thus obtained) at (two) separate places; multiply (one) by (the number of) intercalary months in a *yuga*, which are 15,93,336 in a *yuga*; and divide (the product) by 5184 *into* 10,000 (i.e., by 5,18,40,000). Add the (resulting complete) intercalary months to the result placed at the other place. Then multiply (that sum) by 30 and (to the product) add the (lunar) days (i.e., *tithis*) expired (of the current month). Set down (the result thus obtained) in two places; multiply (one) by the (number of) omitted lunar days in a *yuga*, i.e., by 2,50,82,580, and divide by 1,60,30,00,080. The resulting (complete) omitted lunar days when subtracted from the result put at the other place give the (required) *ahargaṇa*. The remainder obtained on dividing (the *ahargaṇa*) by 7 gives the day beginning with Friday at sunrise (at Laṅkā).[1]

The above rule tells us how to calculate the *ahargaṇa*, i.e., the number of mean civil days elapsed at mean sunrise at Laṅkā[2] on a given lunar day (*tithi*), since the beginning of Kaliyuga. The beginning of Kaliyuga, which is taken as the starting point of the reckoning of *ahargaṇa* in the above rule, occurred on Friday, February 18, B.C. 3102, at mean sunrise at Laṅkā, when the Sun, Moon, and the planets are supposed to have been in conjunction at the first point of the *nakṣatra* Aśvinī (which is a fixed point situated near the star ζ-Piscium). The duration of Kaliyuga, according to Āryabhaṭa I, is 10,80,000 solar years. Four times this (i.e., 43,20,000 solar years) is the duration of a bigger period called a *yuga* (or *mahā-yuga*).

The following table gives the number of lunar months, solar months, intercalary months (i.e., lunar months minus solar months), lunar days, civil days, and omitted lunar days (i.e., lunar days minus civil days) in a *yuga*:

Months and Days in a *Yuga*	
Lunar months	5,34,33,336
Solar months	5,18,40,000
Intercalary months	15,93,336
Lunar days	1,60,30,00,080
Civil days	1,57,79,17,500
Omitted lunar days	2,50,82,580

[1] Cf. *MBh*, i. 4-6; vii. 6-7.

[2] Laṅkā is a hypothetical place on the equator where the meridian of Ujjain (long 75°52′ E from Greenwich) intersects it.

A lunar month is reckoned in Hindu astronomy from one conjunction of the Sun and Moon to the next. The first month of the year is called Caitra. A solar month is reckoned from the Sun's one transit into a sign to the next. A civil day is reckoned from one sunrise to the next.

The Śaka era referred to in the above rule started exactly 3179 solar years after the beginning of Kaliyuga. The following example will illustrate the above rule :

Example. Calculate the *ahargaṇa* for January 1, 1963 A.D.

From the Hindu Calendar we find that January 1, 1963 A.D., falls on Tuesday, the 6th lunar day (*tithi*), in the light half of the 10th month (Pauṣa), in the Śaka year 1884 (elapsed). We therefore proceed as follows.

Calculation :

Adding 3179 to 1884, we get 5063. ... ... (1)

Multiplying this by 12 and adding 9 (i.e., the number of lunar months elapsed since the beginning of Caitra), we get 60,765. ... (2)

Multiplying this by 15,93,336 and dividing the product by 5,18,40,000, we get 1867 as the quotient. (The remainder is discarded, as it is not needed). .. .. (3)

Adding this number (i.e., 1867) to the previous one (i.e., 60,765), we get 62,632. .. .. (4)

Multiplying this by 30 and adding 5 (i.e., the number of lunar days elapsed since the beginning of the current month) to the product, we get 18,78,965. .. .. (5)

Multiplying this by 2,50,82,580, and dividing the product by 1,60,30,00,080, we get 29,400 as the quotient. (The remainder is discarded, as it is not needed.) .. .. (6)

Subtracting this number (i.e., 29,400) from the previous one (i.e., 18,78,965) we get 18,49,565. ... . (7)

This is the required *ahargaṇa*.

Verification :

Dividing this *ahargaṇa* by seven, we get 4 as the remainder. This shows that January 1, 1963 A.D., falls on the 5th day counted with Friday, i.e., on Tuesday, which is correct.

Explanation :

Result (1) gives the number of solar years elapsed since the beginning of Kaliyuga.

Result (2) gives the number of mean solar months elapsed up to the beginning of the 10th mean solar month of the current year.

Result (3) gives the number of complete mean intercalary months corresponding to (2).

Result (4) gives the number of mean lunar months elapsed up to the beginning of the 10th mean lunar month of the current year.

Result (5) gives the number of mean lunar months up to the beginning of the 6th mean lunar day of the 10th mean lunar month of the current year.

Result (6) gives the number of complete mean omitted lunar days corresponding to (5).

Result (7) gives the number of mean civil days up to mean sunrise (at Laṅkā) on the 6th mean lunar day of the 10th mean lunar month of the current year.

Verification shows that this is equal to the number of mean civil days up to mean sunrise (at Laṅkā) on the 6th lunar day of the 10th lunar month of the current year.

Also see my notes on *MBh*, i. 4-6.

The mean lunar day may, sometimes, differ from a true lunar day by *one*, so that the *ahargaṇa* obtained by the above rule may sometimes be in excess or defect by *one*. To test whether the *ahargaṇa* is correct, it should be divided by seven and the remainder counted with Friday. If this leads to the day of calculation, the *ahargaṇa* is correct; if that leads to the preceding day, the *ahargaṇa* is in defect; and if that leads to the succeeding day, the *ahargaṇa* is in excess. When the *ahargaṇa* is found to be in defect, it should be increased by *one*; when it is found to be in excess, it should be diminished by *one*.

Similarly, when a true intercalary month has recently occurred prior to the given lunar month or is about to occur thereafter, the true lunar month may differ from the mean lunar month by *one*. When a true intercalary month has occurred prior to the given month and the intercalary fraction (which is discarded) amounts to *one* month approximately, then the quotient denoting the complete intercalary months is increased by *one*. When a true intercalary month occurs shortly after the given month and the intercalary fraction is small enough, the quotient denoting the complete intercalary months is diminished by *one*.

Revolution-numbers of the planets, etc.,[1] in a period of 43,20,000 solar years (called a *yuga*):

9-14. (In a *yuga*) the revolution-number of the Sun has been stated to be ten thousand times 432 (i.e., 43,20,000); of the Moon, 5,77,53,336; of Mars, 22,96,824; of Jupiter, 3,64,224; of Saturn, 1,46,564; of Mercury and Venus, the same as that of the Sun; of the Moon's apogee (*mandocca*), 4,88,219; of (the *śīghrocca* of) Mercury; 1,79,37,020; and of (the *śīghrocca* of) Venus, 70,22,388. The mean Sun is the *śīghrocca* of the remaining planets. The revolution-number of the Moon's ascending node (*pāta*) is 2,32,226; and the number of civil days (in a *yuga*), 1,57,79,17,500.[2]

The *śīghroccas* of Mercury and Venus are imaginary bodies which are supposed to revolve around the Earth with heliocentric mean angular velocities of Mercury and Venus respectively, their directions from the Earth always remaining the same as those of Mercury and Venus from the Sun. It will thus be seen that the revolutions of Mars, the *śīghrocca* of Mercury, Jupiter, the *śīghrocca* of Venus, and Saturn, given above, are equal to the revolutions of Mars, Mercury, Jupiter, Venus and Saturn respectively around the Sun. The mean longitudes of Mars, the *śīghrocca* of Mercury, Jupiter, the *śīghrocca* of Venus, and Saturn, which are obtained by the rule given below, are therefore, equivalent to the heliocentric mean longitudes of Mars, Mercury, Jupiter, Venus, and Saturn respectively.

A rule for calculating the mean longitudes of the planets for mean sunrise at Laṅkā :

15-17(i). Divide the product of the revolution-number of a planet and the *ahargaṇa* by the (number of) civil days (in a *yuga*); thus are obtained the (number of) revolutions (performed by that planet). From the (successive) remainders multiplied respectively by 12, 30, and 60 and divided by the same divisor (viz. the number of civil days in a *yuga*) are obtained the signs, degrees, and minutes, etc. (of the mean longitude of that planet) for (mean) sunrise (at Laṅkā).[3]

[1] That is, the number of revolutions that the planets, etc., make around the Earth.

[2] Cf. *MBh*, vii. 1-5, 8.

[3] Cf. *MBh*, i. 8.

(In this way should be obtained) the mean longitudes of the planets up to seconds of arc.

The point from which the longitudes are measured in Hindu astronomy is the first point of the *nakṣatra* Aśvinī where the Sun, Moon, and the planets are supdosed to have been situated at the beginning of Kaliyuga, the epoch of reckoning the *ahargaṇa*. The *nakṣatra* Aśvinī is a fixed point on the ecliptic near the star ζ-Piscium.

Correction to be applied to the mean longitudes of the Moon's apogee and the Moon's ascending node obtained by the previous rule:

17(ii-iv). To the (mean) longitude of the Moon's apogee (obtained by the above rule) add three signs and to that of the Moon's ascending node add six signs, and subtract (the latter result) from a circle (i.e., from 360°).[1]

These corrections are made to the longitudes of the Moon's apogee and ascending node, because in the beginning of Kaliyuga their longitudes were $3^s 0° 0' 0''$ and $6^s 0° 0' 0''$ respectively and not $0^s 0° 0' 0''$ as those of the Sun, Moon and the planets. The longitude of the Moon's ascending node is subtracted from 360° because the motion of the Moon's ascending node is retrograde.

Positions of the apogees of the planets:

18. (The longitudes of the apogees of the planets) beginning with Mars are 100 plus 18, 200 plus 10, half a circle (i.e., 180), 90 and 236 degrees respectively.[2]

Dimensions of the epicycles of the planets:

19-21. The *manda* epicycles (of the planets beginning with Mars) are 14, 7, 7, 4, and 9 (in the beginnings of odd quadrants) and 18, 5, 8, 2, and 13 in the (beginnings of) even quadrants. 50 plus 3, 30 plus 1, 16, 59, and 9 have been stated to be the *śīghra* epicycles (of the same planets) (in the beginnings of odd quadrants) and the same diminished respectively by 2, 2, 1, 2, and 1 are their own (*śīghra*) epicycles in the (beginnings of) even quadrants.[3]

[1] Cf. *MBh*, i. 40.

[2] Cf. *MBh*, vii. 13.

[3] Cf. *MBh*, vii. 13-16(i).

The Hindu astronomers generally state the dimensions of the *manda* and *śīghra* epicycles of a planet in terms of degrees and minutes, where a degree stands for the 360th part of the planet's mean orbit and a minute for the 60th part of a degree. The author of the present work, following Āryabhaṭa I, has stated here the dimensions of the *manda* and *śīghra* epicycles of the planets in terms of degrees, after dividing them by $4\frac{1}{2}$. This division has been evidently made to simplify calculation.

These epicycles will be required in the next chapter in finding the true longitudes of the planets.[1]

Position of the Sun's apogee and the epicycles of the Sun and the Moon:

22. (The longitude of) the Sun's apogee, in degrees, is 70 plus 8; his epicycle is 3, and that of the Moon 7.[2]

The previous remark applies to these epicycles also.

Position of the Hindu prime meridian:

23. The line which passes through Laṅkā, Vātsyapura, Avantī, Sthāneśvara, and "the abode of the gods" is the prime meridian.[3]

Laṅkā in Hindu astronomy denotes the place where the meridian of Ujjain (latitude 23°11'N, longitude 75°52'E from Greenwich) intersects the equator. It is one of the four hypothetical cities on the equator, called Laṅkā, Romaka, Siddhapura and Yamakoṭi (or Yavakoṭi). Laṅkā is described in the *Sūrya-siddhānta*[4], as a great city (*mahāpurī*) situated on an island (*dvīpa*) to the south of Bhārata-varṣa (India). The island of Ceylon, which bears the name Laṅkā, however, is not the astronomical Laṅkā, as the former is about six degrees to the north of the equator.

Vātsyapura is the same place as the Vatsagulma of the *Mahā-Bhāskarīya*.[5] It may be identified with the town of Basim or Wasim (pronounced as Bāsim or Vāsim), situated at a distance of 52 miles from the city of Akola

[1] See *infra*, ii. 9-10, 11-13, etc.

[2] Cf. *MBh*, vii. 12(i), 16.

[3] Cf. *MBh*, ii. 1-2.

[4] xii. 37, 39.

[5] ii. 1-2.

in the state of Madhya Bharat.[1] Basim originally was the seat of hermitage of Sage Vatsa and was called Vatsa-gulma.[2] Later on it became a sacred place and grew into a town called Vātsyapura after the name of the sage. Its present name Basim or Wasim is evidently a corrupt form of Vātsam (or Vātsapuram). Basim is now a seat of Hindu religion, famous for its sacred tank called Padma-tīrtha.

The above identification of Vātsyapura or Vatsagulma with Basim seems to be more plausible than our previous identification with Kauśāmbī (modern Kosam), the ancient capital of the Vatsa country, for two reasons :

(1) Basim (longitude 77°11'E from Greenwich) is nearer from the Hindu prime meridian (longitude 75°52'E from Greenwich) than Kauśāmbī (longitude 81°24'E from Greenwich).

(2) Basim fits in the order in which the places lying on the Hindu prime meridian have been stated in the *Mahā-Bhāskarīya*. For, Basim lies to the north of "the White Mountain" and to the south of Avantī (modern Ujjain), as it should be. Kauśāmbī does not fit in that order.

It may, however, be pointed out that the commentator Udaya Divākara seems to identify Vātsyapura with Kauśāmbī, for he writes: "The town called Vātsyapura is well known in the Vatsa country." And we know that Kauśāmbī was the capital of the Vatsa country in ancient times.

Avantī is modern Ujjain in Madhya Bharat.

Sthāneśvara (or Sthāṇvīśvara) is a sacred place in Kurukṣetra, famous for its sacred tank and temple of God Śiva (called Sthāṇu Śiva).[3] It is situated at a distance of about two furlongs from the city of Thanesar in East Panjab.[4]

"The abode of the gods" is Meru, the north pole.

Circumference of the local circle of latitude :

24. 3299 (*yojanas*), (the circumference) of the Earth, multiplied by the Rsine[5] of the colatitude (of the local place), and

[1] See V. V. Mirashi, "Historical data in Dandin's *Daśa-kumāra-carita*", *Nagpur University Journal*, Number 11, December 1945, lines 6-7.

[2] See *Kalyāna*, Tīrthāṅka, p. 229. Also see W. W. Hunter, *The Imperial Gazetteer of India*, Volume II, London (1885), p. 188.

[3] "*sthāneśvaraṁ devāyatanam, tadapi kurukṣetre.*" Udaya Divākara.

[4] See *Kalyāna*, Tīrthāṅka, p. 80.

[5] Rsine means "radius × sine".

divided by the radius (i.e., 3438′) is known as the (Earth's) circumference at the local place.[1]

The Earth's circumference at the local place means "the circumference of the local circle of latitude".

A rule for finding the distance of the local place from the prime meridian :

25-26. The circumference of the Earth multiplied by the difference between the latitudes of (a place on) the prime meridian and the local place and divided by the number of degrees in a circle (i.e., by 360) gives the *bāhu* (i.e., the base of the longitude triangle) due to the local place. The oblique distance from that local place to (the place on) the prime meridian is the hypotenuse (of the triangle). The square root of the difference between the squares of that (hypotenuse) and the *bāhu* is said to be the longitude (in *yojanas* of that place).[2]

The longitude in *yojanas* of a place means the distance of the place from the prime meridian in terms of *yojanas* measured along the local circle of latitude.

In the *Mahā-Bhāskarīya*, the above *bāhu* has been called the *koṭi* (i.e., the upright of the longitude triangle). For details, see my notes on *MBh*, ii.3-4.

Criticism of the above rule :

27. Some learned scholars say like this; others say that it is not so, because of (i) the grossness of the hypotenuse and (ii) the sphericity of the Earth.[3]

Śrīpati (1039 A.D.), too, has criticised the above rule for the same reasons.

Criticism of another rule :

28. (It has been said that) the difference between (the longitude of) the Sun derived from the midday shadow (of the gnomon at the local place)[4] and that calculated for the middle

[1] Cf. *MBh*, ii. 10(iii).
[2] Cf. *MBh*, ii. 3-4.
[3] Cf. *MBh*, ii. 5.
[4] See *infra*, iii. 29-33.

of the day (without the application of the longitude correction) (gives the longitude correction for the Sun). But that is not so, as to the east and west of a place on the prime meridian (i.e., on the same parallel of latitude) the latitude (and therefore the shadow of the gnomon) remains the same.[1]

This rule has also been criticised by Śrīpati, who says:

"Whatever is obtained here as the difference between the longitudes of the Sun derived from the midday shadow (of the gnomon) and that obtained by calculation (for midday, without the application of the longitude correction) when multiplied by the (local) circumference of the Earth and divided by the (Sun's daily) motion gives the *yojanas* of the longitude (i.e., the distance in *yojanas* of the local place from the prime meridian). This is gross on account of the small change in the Sun's declination."[2]

The reader will also note that the longitude derived from the midday shadow will be tropical, whereas the other is not.

A rule for the longitude in time:

29. The difference between the computed and observed times of an eclipse is the longitude in terms of time.[3]

The computed time is the local time for the place lying at the intersection of the prime meridian and the local circle of latitude, while the observed time is the local time for the local place. The difference between the two is obviously the longitude in time for the local place.

It may be pointed out that in Hindu astronomy time is measured from sunrise.

Criterion for knowing whether the local place is to the east or to the west of the prime meridian:

30. If the (lunar and solar) eclipses occur after the calculated time, then the observer is to the east of the prime meridian; otherwise, to the west.[4]

The calculated time is the local time for the place lying at the intersection of the prime meridian and the local circle of latitude.

[1] Cf. *MBh.* ii. 6.
[2] *SiŚe*, ii. 103.
[3] Cf. *MBh*, ii. 7.
[4] Cf. *MBh*, ii. 9.

The longitude correction and its application:

31. The mean daily motion of the planet multiplied by the longitude (of the place) in terms of *ghaṭīs* and divided by 60 should be subtracted (from the mean longitude of the planet for mean sunrise at Laṅkā) (if the place is) to the east of the prime meridian and added (to it) if it is to the west.[1]

Śaṅkaranārāyaṇa gives the following table for the mean daily motion of the planets:

Planet	Moon daily motion correct to seconds of arc Mean
Sun	59′ 8″
Moon	13°10′ 35″
Moon's apogee	6′ 41″
Moon's ascending node	3′ 11″
Mars	31′ 26″
Śīghrocca of Mercury	4° 5′ 32″
Jupiter	4′ 59″
Śīghrocca of Venus	1° 36′ 8″
Saturn	2′

Another rule for finding the distance of the local place from the prime meridian:

32. The *yojanas* (of the distance of the prime meridian) from the local place are obtained on multiplying the longitude in *ghaṭīs* by the local circumference of the Earth and dividing (the product) by 60.[2]

An alternative method for the longitude correction:

33. Whatever is obtained on multiplying the mean daily motion (of the planet) by the *yojanas* (of the distance from the prime meridian) for that place and dividing by its own (local) earth-circumference is to be subtracted from or added to the mean longitude of the planet (for mean sunrise at Laṅkā)

[1] Cf. *MBh*, ii. 10(i).

[2] Cf. *MBh*. ii. 10(ii).

(according as the local place is to the east or to the west of the prime meridian).

Application of the longitude correction to the mean longitude of a planet for mean sunrise at Laṅkā gives the longitude of the planet for mean sunrise at the place where the local meridian intersects the equator. The place where the local meridian intersects the equator is called *svanirakṣa* (i.e., "local equatorial place"),

Justification of the longitude correction :

34. The method of adding or subtracting motion corresponding to the longitude (of the local place) in *ghaṭīs* (taught above) is the cause of the decreased or increased *tithi*[1] (i.e., the local time of observation of the eclipse); seeing is unaffected by that correction.

Śaṅkaranārāyaṇa comments on this verse as follows: "The rule which has been stated here in accordance with which the correction obtained from the longitude, in *ghaṭīs* or *yojanas*, is to be subtracted from or added to the mean longitude of (the Sun and) the Moon according to the direction of the local place (east or west of the prime meridian) is the cause of the decrease or increase of the *tithi* (i.e., of the local time of observation of an eclipse). Therefore the previous remark that by those who are situated to the east of the prime meridian an eclipse is seen after the time calculated for its occurrence (on the meridian of Laṅkā), and by those who are situated to the west of the prime meridian it is seen in advance (of the calculated time) remains unaffected. How? For the time of occurrence of an eclipse as obtained by subtracting the longitude of the Sun from that of the Moon without making allowance for the longitude correction is certainly less or greater than the local time which is obtained by properly subtracting or adding the longitude correction. Therefore at new moon or full moon an eclipse is naturally seen on the two sides (of the prime meridian) after or before the time calculated for its occurrence (on the meridian of Laṅkā). Otherwise (i.e., if the longitude-correction be not made), the difference between the times of observation of an eclipse by those situated to the east and to the west (of the prime meridian) would not be explained."

Parameśvara observes : "That is the reason for the calculated time (of occurrence of an eclipse on the meridian of Laṅkā) being less or greater than

[1] See Glossary.

the local time of observation. But the calculated time (of occurrence of an eclipse) obtained after the correction for longitude has been applied does not differ from that (i.e., the local time of observation)."

Similar remarks have also been made by Udaya Divākara.

Demonstration of the justification of the longitude correction:

35. When at a certain *nāḍikā*[1] (of local time) the Moon is at the point of emersion and is (at the same time) at the point of setting here (i.e., at a place on the prime meridian), then (at the same local time) (people residing) in the west (of that place) say: "The Moon sets after its separation from the shadow" and (those living) in the east (of that place) say: "The Moon sets with the eclipse".[2]

Udaya Divākara comments: "For people residing on the same parallel of latitude the lengths of day and night being equal, the Moon is seen to set as many *ghaṭīs* after sunrise (or sunset) in the countries which lie to the east or west of a place on the prime meridian as in the place on the prime meridian. But in the west the Moon as separated from the shadow is seen. The Moon at the point of separation as observed on the prime meridian is seen there earlier. So the (corresponding) *tithi* (i.e., the local time of observation of the separating Moon) is smaller. Therefore, in order to get that (*tithi*) the motions corresponding to the intervening time should be added to the longitudes of the Sun and the Moon. Similarly, in the east the eclipsed Moon is observed; the separating Moon is seen later, and so the corresponding *tithi* is greater than the other. So here also the motions (corresponding to the intervening time) are rightly subtracted."

The word *nāḍikā* in the opinion of Udaya Divākara denotes the *nāḍīs* of the time in the night when the Moon separating from the shadow at moonset is seen on the prime meridian.

According to the commentator Parameśvara the word *nāḍikā* is used in the sense of time in general (moment, etc.). So according to him the verse would be translated as follows:

[1] i.e., instant.

[2] In his comm. on *Ā*, i. 2, Bhāskara I writes: "A lunar eclipse which occurs here when one *ghaṭī* has elapsed in the night is said to occur at the end of the day by those who live at a distance of one *ghaṭī* (of longitude) towards the west and to occur later (in the night) by those who reside towards the east".

"When the Moon is (just) setting at the end of an eclipse here (at a place on the prime meridian), then for those situated to the west the Moon sets after the eclipse is over whilst for those situated to the east it has set with the eclipse."

Or, literally as follows:

"When the Moon is at the point of separation (from the shadow at the end of a lunar eclipse) and is (at the same time) at the point of setting here (at a place on the prime meridian), then in the west (of that place) (people say): "The Moon has set after its separation (from the shadow)", and those in the east say: "There is eclipse."

Consequences of improper application of the longitude correction:

36. When improper (*viparīta*) application of the positive-negative (longitude) correction (to the longitudes of the Sun and the Moon) is made the resulting *tithi* is not the correct one. (Also) the results derived from (the correct) procedure become otherwise and the motion of the planet also becomes different.

Śaṅkaranārāyaṇa interprets this stanza thus: "(By the word *viparīta* is meant the case) when at the place where the correction for the longitude has been stated to be negative (positive) it is applied contrarily, i.e., positively (negatively). Or, the word *viparīta* may mean that the correction for the longitude is not made at all. The *tithi* obtained in both these cases is not considered to be correct for the purposes of religious sacrifices, etc. Without making allowance for the longitude correction the planetary motion is also incorrect."

Paramśevara says: "When the correction for the longitude is applied contrarily to that stated, the *tithi* obtained is incorrect for the purposes of religious sacrifices, etc. The calculated time of occurrence of an eclipse is also different from the time of actual observation. The positions of the planets are also wrong."

The first half of the verse may also be translated as follows:

"When improper application of the positive-negative (longitude) correction (to the longitudes of the Sun and the Moon) is made, the (computed) *tithi* (i.e., time of an eclipse) does not tally with that of observation."

This translation is in agreement with the interpretations of Udaya Divākara and Parameśvara.

Comparison of the longitude correction with the *lambana* correction :

37. The *lambana* correction is (also) additive or subtractive to the *tithi* and to the longitudes of the Sun and the Moon for that time, but the law of this (positive-negative) correction in the case of the longitude is different from that of the *lambana*.

The term *lambana* means the difference between the parallaxes in longitude of the Sun and the Moon. For the *lambana* correction, see *infra*, chapter V, stanzas 8-10. The *tithi* in the above passage stands for the time of conjunction in longitude of the Sun and the Moon (called *parva-tithi*, or simply *parva*).

Udaya Divākara reads *tadvat* in place of *tasya* and interprets the verse as follows :

"Since the *lambana* correction is applied positively (or negatively) to the longitudes of the Sun and the Moon and exactly in the same way it is positively (or negatively) applied to the time of the *tithi*, therefore the process of the longitude correction is not like that of the *lambana* correction."

He continues:

"This is what has been said : In the case of the *lambana* correction, when the corresponding motions are added to the longitudes of the Sun and the Moon, then the *parva* (i.e., the time of conjunction of the Sun and Moon) is also increased by that time. When the motions corresponding to the *lambana* are subtracted from the longitudes (of the Sun and the Moon) then the *parva* is also diminished by that time. Here (in the case of the longitude correction) it is just the reverse. For, when the longitudes of the Sun and the Moon are increased, the *parva* is diminished ; and when the longitudes of the Sun and the Moon are diminished, the *parva* is increased. The *lambana* and the longitude corrections being thus of unlike natures, the longitude correction is incomparable with the other."

CHAPTER II

TRUE LONGITUDES OF THE PLANETS

Definitions of the Sun's mean anomaly and the corresponding *bhujā* and *koṭi* :

1-2(i). The mean longitude of the Sun diminished by the longitude of the (Sun's) apogee is (called) the (Sun's mean) anomaly. There (in that anomaly) three signs form a quadrant. In the odd quadrant, the arc traversed and the arc to be traversed are known as *bhujā* (or *bāhu*) and *koṭi* (respectively); in the even quadrant, (they are known as) *koṭi* and *bhujā* (or *bāhu*) respectively. This is the position.[1]

That is,

Sun's mean anomaly = Sun's mean longitude — longitude of Sun's apogee.

And if the Sun's anomaly be θ degrees, then

$$\left.\begin{matrix} bhujā=\theta \\ koṭi=90°-\theta \end{matrix}\right\}, \quad \left.\begin{matrix} 180°-\theta \\ \theta-90° \end{matrix}\right\}, \quad \left.\begin{matrix} \theta-180° \\ 270°-\theta \end{matrix}\right\}, \text{ or } \left.\begin{matrix} 360°-\theta \\ \theta-270° \end{matrix}\right\},$$

according as $0 < \theta < 90°$, $90° < \theta < 180°$, $180° < \theta < 270°$, or $270° < \theta < 360°$.

A rule for calculating the Rsines of the *bhujā* and *koṭi* :

2(ii)-3(i). After converting the *bhujā* and the other (i.e., the *koṭi*) into minutes of arc and dividing by 225, (in each case) take (the sum of) as many Rsine-differences as the quotient. Then multiply the remainder (in each case) by the current (i.e., next) Rsine-difference and divide by 225 and add the result (to the corresponding sum of the Rsine-differences obtained above). (The sums thus obtained are the Rsines of the *bhujā* and the *koṭi*).[2]

---

[1] Cf. *MBh*, iv. 1, 8(i).

[2] Cf. *MBh*, iv. 3-4(i).

This rule tells us how to find the Rsine ("radius × sine") of the *bhujā* or *koṭi* (or of any given arc or angle) with the help of the following table of Rsine-differences given by Āryabhaṭa I:

Table of Rsine-differences

Serial No.	Rsine-differences in minutes	Serial No.	Rsine-differences in minutes	Serial No.	Rsine-differences in minutes	Serial No.	Rsine-differences in minutes
1	225	7	205	13	154	19	79
2	224	8	199	14	143	20	65
3	222	9	191	15	131	21	51
4	219	10	183	16	119	22	37
5	215	11	174	17	106	23	22
6	210	12	164	18	93	24	7

The Rsine-differences referred to in the above rule are those of this table.

Suppose that *bhujā* =24°. Then, according to the above rule, Rsine 24° will be obtained as follows:

Converting the *bhujā* into minutes (of arc), we get 1440′. Dividing this by 225, we get 6 as the quotient and 90′ as the remainder. So taking the sum of the first six Rsine-differences, we get

$$225'+224'+222'+219'+215'+210'=1315'.$$

Now multiplying the remainder, i.e., 90′, by the next (i.e., 7th) Rsine-difference (i.e., 205) and dividing by 225, we get

$$\frac{90'\times 205}{225}=82'.$$

Adding this to the previous sum of six Rsine-differences, we get 1315+82′=1597′. This is the required value of Rsin 24°.

Calculation of the *bhujāphala* and the *koṭiphala* :

3(ii). They (i.e., the Rsines of the *bhujā* and the *koṭi*) multiplied by the (planet's tabulated) epicycle should be divided by 80 : the results are (known as) *bhujāphala* and *koṭiphala*. [1]

That is,

$$bhujāphala = \frac{\text{Rsin } (bhujā) \times \text{tabulated epicycle}}{80},$$

$$koṭiphala = \frac{\text{Rsin } (koṭi) \times \text{tabulated epicycle}}{80}.$$

In the case of the Sun and the Moon, the *bhujāphala* corresponds to the equation of the centre of modern astronomy.

For details, the reader is referred to my notes on *MBh*, iv. 6.

Application of the *bhujāphala* correction:

4(i). The *bhujāphala* is additive or subtractive according as the (mean) anomaly is in the half-orbit commencing with the sign Libra or in that commencing with the sign Aries. [2]

In other words, the *bhujāphala* is additive or subtractive according as the mean anomaly is greater than 180° or less than 180°.

The *bhujāphala* correction is applied to the Sun's mean longitude as corrected for the longitude correction. This correction having been applied we obtain the Sun's true longitude for mean sunrise at the 'local equatorial place' (i.e., at the place where the local meridian intersects the equator).

Calculation and application of the *bhujāntara* (or *bhujāvivara*) correction:

4(ii). So also is applied (the *bhujāntara* correction) which is obtained by multiplying the (mean daily) motion of the planet by the (Sun's) *bhujāphala* and dividing by the number of minutes of arc in a circle (i.e., 21600). [3]

[1] Cf. *MBh*, iv. 4, 8(ii).

[2] Cf. *MBh*, iv. 6.

[3] Cf. *MBh*, iv. 7.

That is,

$$bhujāntara \text{ correction} = \frac{\text{Sun's } bhujāphala \times \text{planet's mean daily motion}}{21600}.$$

This correction is subtracted from or added to the Sun's true longitude for mean sunrise at the local equatorial place, according as the Sun's *bhujāphala* is subtractive or additive. Thus we obtain the Sun's true longitude for true sunrise at the local equatorial place.

The *bhujāntara* correction is, thus, the correction for the equation of time due to the Sun's equation of the centre (i.e., due to the eccentricity of the ecliptic).

Approximate formulae for the *bhujāntara* corrections for the Sun and the Moon :

5. One-sixth of the (Sun's) *bhujāphala* is, in seconds of arc, (the *bhujāntara* correction) for the Sun; that for the Moon is obtained in minutes of arc etc. by multiplying (the Sun's *bhujāphala*) by 3 and dividing by 82.

That is,

$$bhujāntara \text{ correction for the Sun} = \frac{\text{Sun's } bhujāphala}{6} \text{ seconds;}$$

and

$$bhujāntara \text{ correction for the Moon} = \frac{\text{Sun's } bhujāphala \times 3}{82} \text{ minutes.}^1$$

These formulae can be easily derived from the previous rule. For other similar formulae see *KK*, i. 18 and *SiŚe*, iii. 46(ii).

A rule for finding the true distances of the Sun and the Moon in minutes (called *mandakarṇa*):

6-7. Increase or diminish the radius by the (Sun's) *koṭiphala* (according as the mean Sun is) in the half-orbit commencing with the anomalistic sign Capricorn or in that commencing with Cancer. The square root of the sum of the squares of that and the (Sun's) *bāhuphala* is the (first approximation to the Sun's) distance. (Severally) multiply that by the (Sun's) *bāhuphala* and *koṭiphala* and divide (each product) by the radius: (the

[1] It is assumed that the Sun's *bhujāphala* is in minutes.

results are again the Sun's *bāhuphala* and *koṭiphala*). (Making use of them calculate the Sun's distance afresh: thus is obtained the second approximation to the Sun's distance). (Repeat this process again and again and thus) by the method of successive approximations obtain the nearest approximation to the Sun's (true) distance. For the Moon, too, this is to be regarded as the method for finding the nearest approximation to the true distance.[1]

The distance obtained by the above method is in terms of minutes and is called *mandakarṇa*. As it is based on the method of successive approximations, it is also known as *asakṛtkalākarṇa* or *aviśeṣakarṇa*.

For the *rationale*, see my notes on *MBh*, iv. 9-12.

A rule for finding the true daily motion (called *karṇabhukti*) of the Sun and the Moon:

8. Multiply the mean daily motion (of the Sun) by the radius and divide (the product) by the (Sun's true) distance (in minutes): the result is the Sun's true daily motion (known as *karṇabhukti* or *karṇasphuṭabhukti*). For the Moon, too, this is the method.[2]

That is,

$$\text{Sun's true daily motion } (karṇabhukti) = \frac{\text{Sun's mean daily motion} \times R}{\text{Sun's true distance in minutes}},$$

$$\text{Moon's true daily motion } (karṇabhukti) = \frac{\text{Moon's mean daily motion} \times R}{\text{Moon's true distance in minutes}}$$

where R is the standard radius (=3438′).

The true daily motion obtained by the above formulae was called *karṇabhukti* (meaning, "motion derived from the distance") because it was obtained by proportion from the true distance of the Sun or Moon.

A rule for the determination of the Sun's true daily motion (called *jīvābhukti*):

9-10. Divide by 225 the (Sun's) mean daily motion as multiplied by the current Rsine-difference. Multiplying the result

[1] Cf. *MBh*, iv. 9-12.

[2] Cf. *MBh*, iv. 13.

(thus obtained) by its (tabulated) epicycle and dividing by 80, subtract that from the Sun's mean daily motion if the (Sun's) anomaly is in the half-orbit commencing with Capricorn and add that to the same if (the Sun's anomaly is) in the half-orbit commencing with Cancer. (The sum or difference thus obtained) is known as the (Sun's) true daily motion.[1]

Let M and M' be the mean longitudes and S and S' the true longitudes of the Sun at sunrise yesterday and today respectively. Also let θ and θ' be the corresponding values of the *bhujā* (due to the Sun's mean anomaly). Then, we have

$$S = M \mp \frac{\text{Rsin } \theta \times r_1}{80},$$

$$\text{and } S' = M' \mp \frac{\text{Rsin } \theta' \times r_1}{80},$$

where r_1 is the Sun's tabulated epicycle, $-$ or $+$ sign being taken according as the Sun's mean anomaly is less than or greater than 180°.

Therefore

$$S' - S = (M' - M) \mp \frac{(\text{Rsin } \theta' \sim \text{Rsin } \theta) \times r_1}{80}$$

$$= m \mp \frac{(\text{Rsin } \theta' \sim \text{Rsin } \theta) \times r_1}{80},$$

where m denotes the Sun's mean daily motion, $-$ or $+$ signs being taken according as the Sun is in the first and fourth or in the second and third anomalistic quadrants.

Neglecting the motion of the Sun's apogee and assuming that the Rsines vary uniformly, we have

$$\text{Rsin } \theta' - \text{Rsin } \theta = \frac{(\text{current Rsine-difference}) \times m}{225} \text{ approx.}$$

Therefore

$$S' - S = m \mp \frac{(\text{current Rsine-difference}) \times m \times r_1}{225 \times 80} \text{ approx.}$$

Hence the above rule.

Since the Sun's true daily motion has been obtained here with the help of Rsines (*jīvā*), therefore it is generally called *jīvābhukti*.

---

[1] Cf. *MBh*, iv. 14.

A rule for finding the Moon's true daily motion (known as *jīvābhukti*) :

11-13. From the (mean daily) motion of the (Moon's) mean anomaly subtract the preceding or succeeding arc (of the current element of the arc, i.e., the elementary arc[1] containing the Moon) (according as the Moon is in the odd or even anomalistic quadrant). (Then) take (the tabulated Rsine-differences) on the basis of the (residue in) minutes of the (mean daily) motion of the Moon's mean anomaly, starting from the current Rsine-difference reversely and directly in the odd and even anomalistic quadrants respectively. The results (i.e., the Rsine-differences) corresponding to the fractions of the first and last elementary arcs should be determined by proportion (and added to the sum of the previous Rsine-differences). The Rsine-difference (corresponding to the daily motion of the Moon's mean anomaly) thus obtained multiplied by the (Moon's tabulated) epicycle and divided by 80 should be subtracted from or added to the Moon's mean daily motion as before (in the case of the Sun, i.e., according as the Moon's anomaly is in the half-orbit commencing with the sign Capricorn or in that commencing with the sign Cancer). This is known as (the Moon's) true (daily motion).[2]

The commentator Parameśvara explains the above method as follows: "From the mean (longitude) of the Moon subtracting its apogee, (then) obtaining the (corresponding) *bhujā*, (then) reducing that to minutes of arc, (then) dividing that by 225, (then) setting down separately the preceding portion of the current elementary arc as also the succeeding one, (then), the (anomalistic) quadrant being odd, having multiplied the preceding portion of the current element of the arc by the current Rsine-difference and divided by 225 and taken (down) the resulting Rsine-difference, subtract the preceding portion of the current elementary arc from the (daily) motion of the Moon's mean anomaly. Then, having divided that remainder by 225, add to the Rsine-difference obtained before as many (tabulated) Rsine-differences,

[1] The twenty-four divisions of a quadrant, each equal to 225', the Rsine-differences of which have been tabulated by Āryabhaṭa I, are called "elements of arc", or "elementary arcs".

[2] Cf. *MBh*, iv. 15-17.

in the inverse order, from the current Rsine-difference as the quotient-number. Then having multiplied the remainder, in minutes of arc, obtained (above) by dividing the (daily) motion of the (Moon's) mean anomaly by 225, by the next Rsine-difference, in the inverse order, and divided by 225, add the resulting Rsine-difference, too, to the Rsine-difference obtained before (by addition). This is (the process) in the odd anomalistic quadrant. In the even (anomalistic) quadrant, on the other hand, having multiplied the succeeding portion of the current elementary arc by the current Rsine-difference and divided that by 225 and (then) having taken the resulting Rsine-difference, subtract from the (daily) motion of the (Moon's) mean anomaly the succeeding portion of the current elementary arc. Also, then, take, in the direct order, the Rsine-differences resulting from the remaining motion of the (Moon's) mean anomaly. Thus are to be taken the Rsine-differences in the inverse and direct order. If here (i.e., in the above process) the Rsine-differences to be taken in the inverse order come to an end (due to the end of the odd quadrant falling within the arc corresponding to the motion of the Moon's anomaly), then for the remaining arc take the Rsine-differences in the direct order. When the Rsine-differences to be taken in the direct order come to an end, then take the Rsine-differences in the inverse order. There (i.e., in such cases) for the Rsine-differences taken in the direct and inverse order motion-correction is obtained separately. Having mutiplied the Rsine-difference (corresponding to the daily motion of the Moon's mean anomaly), thus obtained, by her (tabulated) epicycle viz. 7 and divided (that) by 80, the result should, as before, be subtracted from or added to the (Moon's) mean (daily) motion (according as the Moon is) in the half-orbit beginning with the (anomalistic) sign Capricorn or in that beginning with Cancer. Where, however, there are (two) corrections derived from the Rsine-differences taken in the direct order as well as in the inverse order, there the two corrections are applied to the mean (daily) motion (of the Moon) in accordance with their (anomalistic) quadrants. That is the true (daily)motion (of the Moon)."

The *rationale* of the above rule is exactly similar to that of the previous one. The difference is that the motion of the Moon's apogee is also taken into account in this case.

Defects of the *jīvābhukti* :

14-15(i). (According to the rules stated above) whilst the Sun or the Moon moves in the (same) element of arc[1], there is

[1] *Vide supra*, p. 22 footnote (1)

no change in the rate of motion because (the current Rsine-difference being fixed throughout that element) the Rsine-difference does not decrease or increase : when viewed in this way, this *jīvābhukti* is defective.

Rule 9-10 shows that so long as the Sun remains in the same elementary arc (measuring 225′) the Sun's *jīvābhukti* does not vary. Since the Sun remains in the same element for three consecutive days, its *jīvābhukti* remains the same for three consecutive days. This is defective, because the rate of motion varies from instant to instant.[1]

Similarly, so long as the Moon remains in the same elementary arc, its velocity remains the same because throughout that element the Rsine-difference is constant. Thus, in the case of the Moon, the instantaneous daily motion obtained with the help of the Moon's current Rsine-difference is defective.

Author's opinion regarding the true daily motion :

15(ii). The *karṇabhukti*[2] or the difference between the true (longitudes) for two consecutive days is the true (daily) motion.

The commentator Parameśvara thinks that the *karṇabhukti* is the instantaneous daily motion.

The comparative merits and demerits of the *jīvābhukti* and the *karṇabhukti* have been examined in detail by Nīlakaṇṭha in his commentary on *Ā*, ii.22-25.

A rule for finding the Sun's declination with the help of the Sun's tropical (*sāyana*) longitude :

16. 1397 is (in minutes of arc) the Rsine of the (Sun's) greatest declination. The product of that and the Rsine of the *bhujā* due to the Sun's true (tropical) longitude divided by the radius is the Rsine of (the Sun's) desired declination.[3]

---

[1] Instantaneous change of velocity was recognised by the Hindu astronomer Mañjula (932) who, on the basis of the idea of the "infinitesimal increment", gave a rule for the instantaneous velocity of a planet.

[2] See stanza 8 above.

[3] Cf. *MBh*, iii. 6(i).

That is,

$$\text{Rsin } \delta = \frac{\text{Rsin } (bhujā\ \lambda) \times 1397'}{R};$$

where δ is the Sun's declination and λ the Sun's longitude.

In Fig. 1, let S denote the position of the Sun on the celestial sphere, SL the perpendicular from S on the plane of the celestial equator, and SM the perpendicular from S on the line joining the first point of Aries and the first point of Libra. Then in the plane triangle SLM, we have

$$SL = \text{Rsin } \delta,$$

$$SM = \text{Rsin } (bhujā\ \lambda),$$

$$\angle SML = \epsilon,$$

$$\angle SLM = 90°.$$

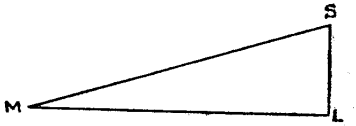

Fig. 1

Therefore

$$SL/SM = \text{Rsin } \epsilon \ /\ \text{Rsin } 90°,$$

giving

$$\text{Rsin } \delta = \frac{\text{Rsin } \epsilon \times \text{Rsin } (bhujā\ \lambda)}{R}$$

$$= \frac{\text{Rsin}(bhujā\lambda) \times 1397'}{R},$$

taking Rsin $\epsilon = 1397'$.

A rule for finding the earthsine and the ascensional difference for the Sun:

17-18. Whatever be the square root of the difference between the squares of that (i.e., of the Rsine of the Sun's declination) and of the radius is the (Sun's) day-radius. The Rsine of the latitude multiplied by the Rsine of the (Sun's) declination and divided by the Rsine of the colatitude is (known as) the (Sun's) earthsine. This is multiplied by the radius and divided by the (Sun's) day-radius: whatever is obtained is called the Rsine of the (Sun's) ascensional difference.[1]

The Sun's day-radius is the radius of the Sun's diurnal circle, along which the Sun moves in its diurnal motion. It is equal to the Rsine of the Sun's codeclination. Hence

$$\text{day—radius} = \sqrt{(R^2 - \text{Rsin } \delta)^2},$$

where δ is the Sun's declination.

[1] Cf. *MBh*, iii. 6(ii)—7.

The Sun's earthsine is the distance between (1) the Sun's rising-setting line and (2) the line joining the points of intersection of the Sun's diurnal circle and the six o'clock circle.

In Fig. 2, let K be the point of intersection of the Sun's diurnal circle and the six o'clock circle, KB the perpendicular from K on the Sun's rising-setting line, and KA the perpendicular from K on the east-west line. Then in the triangle KAB, we have

$$KA = R\sin\delta,$$

KB=Sun's earthsine,

$$\angle KBA = 90° - \phi,$$

and $$\angle KAB = \phi.$$

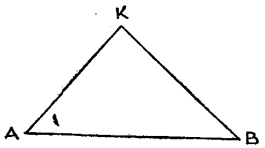

Fig. 2

Therefore we have

$$\frac{\text{Sun's earthsine}}{R\sin\delta} = \frac{R\sin\phi}{R\sin(90-\phi)},$$

or $$\text{Sun's earthsine} = \frac{R\sin\phi \times R\sin\delta}{R\cos\phi}.$$

The Sun's ascensional difference is the arc of the celestial equator lying between (1) the hour circle of the Sun's rising point on the eastern horizon and (2) the six o'clock circle.

It can be seen from the celestial sphere that

$$\frac{R\sin(\text{Sun's ascensional difference})}{\text{Sun's earthsine}} = \frac{R}{R\cos\delta}.$$

Therefore

$$R\sin(\text{Sun's ascensional difference}) = \frac{\text{Sun's earthsine} \times R}{R\cos\delta}.$$

Correction for the Sun's ascensional difference (*cara-saṁskāra*) :

19-20. The minutes of arc in the arc of that (Sun's ascensional difference) are known as *prāṇa* (or *asu*). On multiplying them by the (Sun's) true daily motion and dividing by 21600 are obtained the minutes, etc., (of the Sun's motion corresponding to its ascensional difference). (In order to obtain the Sun's true longitude) at sunrise (for the local place) these (minutes, etc.) should be subtracted (from the Sun's true longitude at sunrise

for the local equatorial place) provided the Sun is in the northern hemisphere (i. e., to the north of the equator) and added if the Sun is in the southern (hemisphere). In the case of sunset, (the law of correction is) the reverse. In the case of midday or midnight, this (correction) should not be performed.[1]

The *asu* is a unit of sidereal time equivalent to 1/21600 of a sidereal day. The Sun's ascensional difference measured in *asus* denotes the time-interval, in *asus*, between the Sun's rising or setting at the local and local equatorial places. The above correction for the Sun's ascensional difference, therefore, makes allowance for the difference between the times of Sun's rising or setting at the local and local equatorial places.

The general formula for the above correction is:

Correction for the Sun's ascensional difference (*cara* correction)

$$= \frac{\text{Sun's asc. diff. in } asus \times \text{planet's true daily motion}}{21600} \text{ minutes of arc.}$$

When the Sun is in the northern hemisphere, sunrise at the local place occurs earlier than at the local equatorial place, and sunset at the local place occurs later than at the local equatorial place. When the Sun is in the southern hemisphere, it is just the contrary. Hence the law of addition and subtraction of the correction.

Since midday or midnight occurs simultaneously at the local and local equatorial places, therefore there is no need of such a correction at that time.

When the above correction has been applied to the Sun's true longitude for true sunrise at the local equatorial place, we get the Sun's true longitude for true sunrise at the local place. This is called the Sun's true longitude.

We thus see that, in the case of the Sun, to obtain the true longitude for true sunrise at the local place we have to apply to the mean longitude for mean sunrise at Laṅkā the following four corrections in their respective order:

(1) the longitude correction,

(2) the *bhujāphala* correction (i.e., the equation of the centre),

(3) the *bhujāntara* correction (i.e., the correction for the equation of time due to the Sun's equation of the centre),

[1] Cf. *MBh*, iv. 26-27(i).

(4) the *cara* correction (i.e., the correction due to the Sun's ascensional difference).

In the case of the Moon, the same four corrections are applied in the following order:

(1) the longitude correction,
(2) the *bhujāntara* correction,
(3) the *bhujāphala* correction,
(4) the *cara* correction.

The correction for the equation of time due to the obliquity of the ecliptic has been neglected by the author of the present work, like all other early Hindu astronomers. This correction occurs for the first time in the works of Śrīpati (1039) and Bhāskara II (1150). Bhāskara II called it *udayāntara-saṁskāra* and prescribed it for all planets.

Lengths of day and night :

21. (When the Sun is) in the northern hemisphere, the day increases and the night decreases by twice the *asus* of the (Sun's) ascensional difference. (When the Sun is) in the southern hemisphere, the contrary is the case.[1]

What is meant is that when the Sun is the northern hemisphere

length of day = 30 *ghaṭīs* + twice the Sun's asc. diff. in *asus*,
and length of night = 30 *ghaṭīs* — twice the Sun's asc. diff. in *asus*,

and when the Sun is in the southern hemisphere

length of day = 30 *ghaṭīs* — twice the Sun's asc. diff. in *asus*,
and length of night = 30 *ghaṭīs* + twice the Sun's asc. diff. in *asus*.

The truth of this can be easily seen from the celestial sphere.

The *bhujāntara* correction for the Moon :

22. The mean daily motion of the Moon multiplied by the Sun's *bhujāphala* and divided by 21600 should be added to or subtracted from the mean longitude of the Moon (corrected for the longitude correction) as in the case of the Sun (i.e., according as the Sun's mean anomaly is in the half-orbit commencing with Libra or in that commencing with Aries).[2]

[1] Cf. *MBh*, iv. 28.
[2] Cf. *MBh*, iv. 29.

Other corrections for the Moon:

23-24. The result in minutes of arc, etc., which is obtained on multiplying the true daily motion of the Moon by the *asus* of the Sun's ascensional difference and dividing (that product) by the number of *asus* in a day and night (i.e., by 21600) should always be added to or subtracted from the true longitude of the Moon (for true sunrise at the local equatorial place) according to (the position of) the Sun.[1] The remaining (*bhajāphala*) correction for the Moon is applied (to the Moon's longitude corrected for the longitude and *bhujāntara* corrections) in the same manner as in the case of the Sun.[2]

The correction stated in the first part of the above passage is the Moon's *cara-saṁskāra*, i.e., correction to the Moon's longitude due to the Sun's ascensional difference.

The *bhujāphala* correction for the Moon, which is to be applied before the *cara* correction, is given by the formula:

bhujāphala correction for the Moon

$$= \mp \frac{\text{Rsin}\{\textit{bhujā} \text{ due to Moon's mean anomaly}\} \times \text{Moon's tabulated epicyle}}{80},$$

− or + sign being taken according as the Moon's mean anomaly is less or greater than 180°.

From the above, we see that in the case of the Moon, the order of the corrections to be applied is, as stated before, as follows:

(1) the longitude correction,

(2) the *bhujāntara* correction (i.e., correction due to the Sun's equation of the centre),

(3) the *bhujāphala* correction (i.e., the Moon's equation of the centre),

(4) the *cara* correction (i.e., correction due to the Sun's ascensional difference).[3]

[1] *Vide supra*, stanzas 19-20.

[2] Cf. *MBh*, iv. 29-30.

[3] The commentator Parameśvara suggests, as an alternative, the application of the *cara* correction before the *bhujāphala* correction.

The next five stanzas relate to the application of the true longitudes of the Sun and the Moon to the computation of three of the elements of the Hindu Calendar (Pañcāṅga), viz , *nakṣatra, tithi* and *karaṇa* and to the determination of the phenomena of *vyatīpāta*. It must be noted that the calculations for *nakṣatra, tithi* and *karaṇa* are the made for sunrise.

Calculation of the *nakṣatra* :

25-26(i). (The true longitude of) the Moon reduced to minutes of arc should be divided by 800: the quotient (thus obtained) denotes the (number of) *nakṣatras* Aśvinī, etc., (passed over by the Moon). The traversed and the untraversed portions (of the current *nakṣatra*) should be divided by the true daily motion (of the Moon in minutes of arc) after having multiplied them by 60: thus are obtained the *nāḍīs* elapsed and to elapse at sunrise.[1]

Beginning with the first point[2] of the *nakṣatra* Aśvinī, the ecliptic is divided into 27 parts, each of 800 minutes of arc. These parts are called *nakṣatras* and are given the same names as the zodiacal asterisms, i. e.,

1. Aśvinī	8. Puṣya	15. Svātī	22. Śravaṇa
2. Bharaṇī	9. Āśleṣā	16. Viśākhā	23. Dhaniṣṭhā
3. Kṛttikā	10. Maghā	17. Anurādhā	24. Śatabhiṣak
4. Rohiṇī	11. Pūrvā Phālgunī	18. Jyeṣṭhā	25. Pūrva-Bhādrapada
5. Mṛgaśirā	12. Uttarā Phālgunī	19. Mūla	
6. Ārdrā	13. Hasta	20. Pūrvāṣāḍha	26. Uttara-Bhādrapada
7. Punarvasu	14. Citrā	21. Uttarāṣāḍha	27. Revatī

The above rule enables us to know the *nakṣatra* in which the Moon lies at sunrise and the time elapsed since she entered that *nakṣatra* as also the time to elapse before she enters the next *nakṣatra*.

---

[1] Cf. *MBh*, iv. 34.

[2] The first point of the *nakṣatra* Aśvinī is the fixed point from which the longitudes of the planets are measured in Hindu astronomy. This point coincides with the junction star of the *nakṣatra* Revatī, i. e., with ζ-Piscium.

Calculation of the *tithi* :

26(ii)–27. Having reduced (the longitude of) the Moon minus (the longitude of) the Sun to minutes of arc, divide it by 720: the quotient is the (number of) *tithis* elapsed (since new moon). On multiplying (the portions of the current *tithi*, elapsed and to be elapsed severally) by 60 and dividing by the difference between the (true) daily motions (of the Sun and Moon) are obtained (the *ghaṭīs*) elapsed and to be elapsed (of the current *tithi*).[1]

A lunar month, which is defined in Hindu astronomy as the period from one new moon to the next, is divided into 30 parts called *tithis* (or lunar days). The first *tithi* begins just after new moon (when the Sun and Moon have the same longitude) and continues till the Moon is 12° (or 720′) in advance of the Sun; the second *tithi* then begins and continues till the Moon is 24° in advance of the Sun; the third *tithi* then begins and continues till the Moon is 36° in advance of the Sun; and so on. The fifteenth *tithi* is called Pūrṇimā or Pūrṇimāsī ("the full moon tithi"), and the thirtieth *tithi* is called Amāvāsyā or Amāvasyā ("the tithi in which the Sun and Moon are in conjuction", i. e., "the new moon tithi").

The first fifteen *tithis* fall in the light half of the lunar month and the remaining fifteen *tithis* in the dark half of the lunar month. The *tithis* falling in either of the two halves are numbered 1, 2, 3, ..., the thirtieth *tithi* being, however, numbered 30.

The rule given above gives the number of *tithis* elapsed since new moon, and the time elapsed at sunrise since the beginning of the current *tithi* as also the time to elapse at sunrise before the commencement of the next *tithi*.

Calculation of the *karaṇa* :

28. The *karaṇas* (elapsed) are obtained by taking "half the measure of the *tithi* (i. e., 360 minutes)" for the divisor, and are counted with Bava. But the number of *karaṇas* elapsed in the light half of the month should be diminished by *one*, whereas those elapsed in the dark half of the month should be increased

[1] Cf. *MBh*, iv. 31-32.

by *one*. This is what has been stated.[4]

A lunar month is also divided into sixty parts called *karaṇas*. These sixty *karaṇas* are divided into eight cycles of seven movable *karaṇas*, bearing the names Bava, Bālava, Kaulava, Taitila, Gara, Vaṇija, and Viṣṭi[2] respectively, and four immovable *karanas*, bearing the names Śakuni, Catuṣpada, Nāga, and Kiṁstughna respectively.

The first round of the movable *karaṇas* begins with the second half of the first *tithi* in the light half of the month, and the eighth round ends with the first half of the fourteenth *tithi* in the dark half of the month. Thus in the light half of the month, the second *karaṇa* is Bava, the third *karaṇa* is Bālava, the fourth *karana* is Kaulava, and so on; and in the dark half of the month, the first *karaṇa* is Bālava, the second *karaṇa* is Kaulava, and so on.

The four immovable *karaṇas* occur in succession after the eighth round of the cycle of the seven movable *karaṇas*.

The following table will clarify the occurrence of the various *karaṇas* with respect to the *tithis*.

---

[1] That is to say: If it is the light half of the month, divide the true longitude of the Moon as diminished by that of the Sun, reduced to minutes, by 360. The quotient diminished by *one* should be divided by seven and the remainder counted with Bava. This gives the *karaṇa* elapsed before sunrise.

If it is the dark half of the month, subtract the longitude of the Sun from that of the Moon, and diminish that difference by six signs. Reduce it to minutes and divide by 360. The quotient increased by *one* should be divided by seven and the remainder counted with Bava. This gives the *karaṇa* elapsed before sunrise.

The time elapsed at sunrise since the beginning of the current *karaṇa* should be determined from the remainder obtained after division by 360 as in the case of the *tithi*.

Cf. *MBh*, iv. 33.

[2] The *karaṇa* Viṣṭi is also known as Bhadrā and is considered inauspicious.

Relative Positions of *Tithis* and *Karaṇas*

Light Half		Dark Half	
tithi	*karaṇa*	*tithi*	*karaṇa*
1. Pratipadā	{Kiṁstughna Bava	1. Pratipadā	{Bālava Kaulava
2. Dvitīyā	{Bālava Kaulava	2. Dvitīyā	{Taitila Gara
3. Tṛtīyā	{Taitila Gara	3. Tṛtīyā	{Vaṇija Viṣṭi
4. Caturthī	{Vaṇija Viṣṭi	4. Caturthī	{Bava Bālava
5. Pañcamī	{Bava Bālava	5. Pañcamī	{Kaulava Taitila
6. Ṣaṣṭhī	{Kaulava Taitila	6. Ṣaṣṭhī	{Gara Vaṇija
7. Saptamī	{Gara Vaṇija	7. Saptamī	{Viṣṭi Bava
8. Aṣṭamī	{Viṣṭi Bava	8. Aṣṭamī	{Bālava Kaulava
9. Navamī	{Bālava Kaulava	9. Navamī	{Taitila Gara
10. Daśamī	{Taitila Gara	10. Daśamī	{Vaṇija Viṣṭi
11. Ekādaśī	{Vaṇija Viṣṭi	11. Ekādaśī	{Bava Bālava
12. Dvādaśī	{Bava Bālava	12. Dvādaśī	{Kaulava Taitila
13. Trayodaśī	{Kaulava Taitila	13. Trayodaśī	{Gara Vaṇija
14. Caturdaśī	{Gara Vaṇija	14. Caturdaśī	{Viṣṭi Śakuni
15. Pūrṇimā	{Viṣṭi Bava	30. Amāvasyā	{Catuṣpada Nāga

The three kinds of *vyatīpāta*:

29. When the sum of the (true) longitudes of the Sun and the Moon amounts to half a circle (i.e., 180°), the phenomenon is called (*lāṭa*) *vyatīpāta*; when that (sum) amounts to a circle (i.e., 360°), the phenomenon is called *vaidhṛta* (*vyatīpāta*); and when that (sum) extends to the end of the *nakṣatra* Anurādhā (i.e., when

the sum amounts to 7 signs, 16 degrees, and 40 minutes), the phenomenon is called *sārpamastaka* (*vyatīpāta*).[1]

The term *vyatīpāta* (or, what is generally known as *pāta* or *mahāpāta*) literally means "a very great portentious calamity". Here it denotes an astronomical phenomenon which is considered to be extremely inauspicious. "The time intervening between the moments of the beginning and end (of the *vyatīpāta*)", says the author of the *Sūrya-siddhānta*, "is to be looked upon as exceedingly terrible, having the likeness of the consuming fire, forbidden for all work. While any part of the discs of the Sun and the Moon have the same declination, so long is there a continuance of this aspect, causing the destruction of all works." "So", he continues, "from a (previous) knowledge of the time of its occurrence, very great advantage is obtained, by means of bathing, giving, prayer, ancestral offerings, vows, oblations, and other like acts."[2] The phenomenon of *vyatīpāta* is said to have a universal effect. According to our author "when the phenomenon of *vyatīpāta* occurs, even on cutting the branches of a milk-tree (*kṣīrataru*), there is absence of milk".[3]

The text describes the three varieties of the *vyatīpāta*, *lāṭa*, *vaidhṛta* and *sārpamastaka*, giving simply the regions of their occurrence. It does not go into the details of their calculation. The subject, however, is so important for the astrologer that works on Hindu astronomy generally include a chapter giving a detailed discussion of this subject.[4]

In modern Hindu Calendars (called Pañcāṅga) are given the *tithi*, *karaṇa*, *nakṣatra* and *yoga* current at sunrise for every day of the year and also the times when they end and the next ones begin. The *yoga* has not been treated by Bhāskara I, but it forms one of the five important elements of the Hindu Calendar. Like the *nakṣatras*, the number of *yogas* is also twenty-seven. The method of finding the number of *yogas* passed over and the time elapsed at sunrise since the commencement of the current *yoga* is similar to that prescribed for the *nakṣatra*. The difference is that in the case of the *yoga* calculation is made with the sum of the longitudes of the Sun and the Moon, whereas in the case of the *nakṣatra* calculation is made with the help of the longitude of the Moon only. The

[1] Cf. *MBh*, iv. 35. Also see *VVSi*, xi. 16-17; *SūSi*, xi. 1-2; *MBh*, iv. 35; *PSi*, iii. 20-22; *ŚiDVr*, I, xii. 1; *BrSpSi*, xiv. 33-34; *MSi*, xiii. 1; *SiŚe*, viii. 1-2; *SiŚi* I, xii. 8; *TS*, vi. 1-2.

[2] Cf. Burgess E., *Sūrya-siddhānta* (English Translation), Calcutta (1935), xi. 16-18.

[3] *asmin kila vyatīpātayoge kṣīrataruśākhāvacchede'pi gatakṣīratā.*

[4] See e.g. *Sūsi*, xi; *BrSpSi*, xiv; *SiŚe*, viii; *SiŚi*, I; xii. *TS*, vi.

first *yoga* (called Viṣkambha) begins when the sum of the longitudes of the Sun and the Moon is zero, and continues till that sum amounts to 13°20′; the second *yoga* (called Prīti) then begins and continues till the sum of the longitudes of the Sun and the Moon amounts to 26°40′ ; and so on.[1]

It is noteworthy that the *sārpamastaka - yvatīpāta* occurs when the seventeenth *yoga*, bearing the name *vyatīpāta*, ends. (See footnote 1).

General instruction regarding the planets :

30. In the *manda* and *śīghra* (operations) of the planets (Mars etc.) the *kendra* (anomaly), (their) *koṭi* and *bhujā*, (their) Rsines, the corresponding *phalas* (corrections) and their addition and subtraction, should be understood as in the case of the Sun.[2]

There is one exception, viz. that the *śīghrakendra* is defined as

śīghrakendra=longitude of planet's *śīghrocca* — longitude of planet,

and not as *mandakendra*, which is defined as

mandakendra=longitude of planet — longitude of planet's *mandocca*.

A rule for finding the corrected epicycle in the case of the planets, Mars, etc :

31-32. One should divide by the radius the Rsine or the Rversed-sine (of the part of the *kendra* lying in the current quadrant[3]) as multiplied by the difference between the epicycles (for the beginnings of the odd and even quadrants) according as the (current) quadrant is odd or even. If the epicycle (in the beginning of the current quadrant) is smaller, add the (above) result to it;

[1] The names of the twenty-seven *yogas* are:—(1) Viṣkambha, (2) Prīti, (3) Āyuṣmān, (4) Saubhāgya, (5) Śobhana, (6) Atigaṇḍa, (7) Sukarmā, (8) Dhṛti, (9) Śūla, (10) Gaṇḍa, (11) Vṛddhi, (12) Dhruva, (13) Vyāghāta, (14) Harṣaṇa, (15) Vajra, (16) Siddhi, (17) Vyatīpāta, (18) Varīyān, (19) Parigha, (20) Śiva, (21) Siddha, (22) Sādhya, (23) Śubha, (24) Śukla, (25) Brahmā, (26) Indra, and (27) Vaidhṛta.

There is another system of twenty-eight *yogas*, beginning with Ānanda. In some Hindu Calendars *yogas* of this system are also given for every day of the month. But these *yogas* are of astrological interest only.

[2] Cf. *MBh*, iv. 37.

[3] The *kendra* is said to be in the first quadrant when it is less than 90°, in the second quadrant when it is between 90° and 180° , and so on.

if the epicycle (in the beginning of the current quadrant) is greater, subtract the (above) result from it. Then is obtained the corrected epicycle. If this correction is not made, the motion (of the planet) would be like the jumping of a frog.[1]

From chapter I, stanzas 19-21, we know that the planets Mars, Mercury, Jupiter, Venus, and Saturn have two types of epicycles, *manda* and *śīghra*, which vary in size from place to place. Their values for the beginnings of odd and even quadrants were tabulated in those stanzas. The above rule gives their values for any other place of the orbit.

Let α and β be the values of the epicycles (*manda* or *śīghra*) of a planet for the beginnings of odd and even quadrants respectively. Then (i) if the planet be in the first anomalistic quadrant, say at P, and its anomaly be θ,

$$\text{epicycle at P} = \alpha + \frac{(\beta - \alpha) \times R \sin \theta}{R}, \text{ when } \alpha < \beta,$$

$$= \alpha - \frac{(\alpha - \beta) \times R \sin \theta}{R}, \text{ when } \alpha > \beta,$$

and (ii) if the planet be in the second anomalistic quadrant, say at Q, and its anomaly be $90° + \phi$,

$$\text{epicycle at Q} = \beta - \frac{(\beta - \alpha) \times R \text{versin } \phi}{R}, \text{ when } \alpha < \beta,$$

$$= \beta + \frac{(\alpha - \beta) \times R \text{versin} \phi}{R}, \text{ when } \alpha > \beta.$$

Similarly in the third and fourth anomalistic quadrants.

A rule relating to the calculation of the true (geocentric) longitudes of the superior planets, Mars, Jupiter, and Saturn :

33-37(i). Having added half the *bāhuphala* due to the *mandocca* (apogee) to or subtracted that from the mean longitude of the planet as before, the result should be subtracted from (the longitude of) the *śīghrocca* : that (difference) is called the *śīghrakendra*. From that obtain the *bāhuphala* : (and) having multiplied that by the radius, divide (the product) by the (*śīghra*)*karṇa*. Half the arc corresponding to the result obtained should be added or subtracted according as the *śīghrakendra* is in the half-orbit beginning with Aries or in that beginning with

[1] Cf. *MBh*, iv. 38-39.

Libra. Then after subtracting (the longitude of) the *mandocca* from that (result), the entire *bāhuphala* (derived from that difference), reduced to arc, should be applied (as correction, positive or negative) to the mean longitude of the planet (according as the *mandakendra* is in the half-orbit beginning with the sign Libra or in that beginning with the sign Aries): this (result) is known as the true-mean longitude (of the planet). (Then) after subtracting the resulting quantity (viz. the true-mean longitude of the planet) from the *śīghrocca*, the entire correction obtained by the *śīghrocca* process, reduced to arc, should be applied (as correction, positive or negative,) to the true-mean longitude of the planet (according as the *śīghrakendra* is in the half-orbit beginning with Aries or in that beginning with Libra): thus is obtained the true longitude of the planet.[1]

This procedure is adopted in the case of Mars, Jupiter, and Saturn.

Thus, in order to obtain the true longitude of Mars, Jupiter, or Saturn, one should proceed as follows:

First calculate the mean longitude of the planet (as corrected for the longitude, *bhujāntara*, and *cara* corrections)[2]. Then subtract therefrom the longitude of the planet's *mandocca* (apogee): this gives the *mandakendra*. Calculate the corresponding *bhujā*, and therefrom the *bhujāphala* by the application of the formula:

$$bhujāphala = \frac{\text{Rsin } (bhujā) \times \text{corrected } manda \text{ epicycle}}{80}. \qquad (1)$$

Subtract half of it from or add that to the mean longitude of the planet, according as the *mandakendra* is less or greater than 180°. Subtract the resulting longitude from the planet's *śīghrocca*: this gives the *śīghrakendra*. Calculate the corresponding *bhujā*, and therefrom the *bhujāphala* by the application of the formula:

$$bhujāphala = \frac{\text{Rsine } (bhujā) \times \text{corrected } śīghra \text{ epicycle}}{80}. \qquad (2)$$

---

[1] Cf. *MBh*, iv. 40-43.

[2] See Parameśvara's commentary. According to the commentator Śaṅkaranārāyaṇa, one should take here the mean longitude as corrected for the longitude and the *bhujāntara* corrections, and should apply the *cara* correction when all the other corrections have been performed.

Multiply this *bhujāphala* by the radius (i.e., 3438′) and divide by the *śīghrakarṇa*, which is equal to

$$[\{R \pm R\sin(koṭi)\}^2 + \{R\sin(bhujā)\}^2]^{\frac{1}{2}}, \quad (3)$$

+ or − sign being taken according as the *śīghrakendra* is in the first and fourth or second and third quadrants.

Then find the corresponding arc. Add half of it to or subtract that from the mean longitude of the planet, already corrected for half the *bhujā-phala* due to *mandakendra*, according as the *śīghrakendra* is less or greater than 180°.

From the result thus obtained subtract the longitude of the planet's *mandocca* (apogee) : this gives the *mandakendra*. Find the corresponding *bhujā*, and therefrom calculate the *bhujāphala* by applying the formula (1) above. Subtract this *bhujāphala* from or add that to the mean longitude of the planet (as corrected for the longitude, *bhujāntara* and *cara* corrections), according as the *mandakendra* is less or greater than 180° : this gives the true-mean longitude of the planet. Subtract this true-mean longitude from the longitude of the planet's *śīghrocca* : this gives the *śīghrakendra*. Find the corresponding *bhujā*, and therefrom, by the application of formula (2) above, calculate the *bhujāphala*. Multiply that by the radius and divide by the *śīghrakarṇa*, obtained afresh by formula (3). Then find the corresponding arc, and add that to or subtract that from the true-mean longitude of the planet, according as the *śīghrakendra* is less than or greater than 180°. The result thus obtained is the true longitude of the planet for true sunrise at the local place.[1]

For the Hindu epicyclic theory on which the above procedure is based, see my notes on *MBh*, iv. 40-44.

A rule relating to the determination of the true (geocentric) longitudes of the inferior planets, Mercury and Venus :

37(ii)-39. The method used in the case of Mercury and Venus is being described now.

First add or subtract half the arc corresponding to the *śīghraphala* in the reverse order (i.e., according as the *śīghrakendra* is in the half-orbit beginning with Libra or in that beginning with Aries) to or from its own *mandocca*. Whatever correction is (then) derived from that (corrected) *mandocca* should, as a whole, be applied as correction to the mean longitude of the

[1] In the case of Mars, Jupiter and Saturn, the true-mean longitude is roughly the true heliocentric longitude and the true longitude, the true geocentric longitude.

planet: then is obtained the true-mean longitude (of the planet). That corrected for (the correction due to) the *śīghrocca* gives the true longitude (of the planet).[1]

That is, first calculate the mean longitude of the planet (as corrected for the longitude, *bhujāntara* and *cara* corrections). Then subtract it from the longitude of the planet's *śīghrocca*: this gives the *śīghra-kendra*. Calculate the corresponding *bhujā*, and therefrom the *bhujāphala* by the application of the formula:

$$bhujāphala = \frac{\text{Rsin } (bhujā) \times \text{corrected } śīghra \text{ epicycle}}{80}. \qquad (1)$$

Multiply that by the radius and divide the product by the *śīghrakarṇa*, which is equal to

$$[\{R \pm \text{Rsin } (koṭi)\}^2 + \{\text{Rsin } (bhujā)\}^2]^{\frac{1}{2}}, \qquad (2)$$

+ or − sign being taken according as the *śīghrakendra* is in the first and fourth or second and third quadrants.

Then find the corresponding arc. Add half of that arc to or subtract that from the mean longitude of the planet's *mandocca* (apogee), according as the *śīghrakendra* is greater or less than 180°. Thus is obtained the corrected longitude of the planet's *mandocca* (apogee).

Now subtract the corrected longitude of the planet's *mandocca* from the mean longitude of the planet: this gives the *mandakendra*. Calculate the corresponding *bhujā*, and therefrom the *bhujāphala* by the application of the formula:

$$bhujāphala = \frac{\text{Rsin } (bhujā) \times \text{corrected } manda \text{ epicycle}}{80}.$$

Subtract it from or add it to the mean longitude of the planet, according as the *manda-kendra* is less or greater than 180°: this gives the true-mean longitude of the planet. Subtract this true-mean longitude from the longitude of the planet's *śīghrocca*: this gives the *śīghrakendra*. Calculate the corresponding *bhujā*, and therefrom the *bhujāphala* by the application of the formula (1)

[1] Cf. *MBh*, iv. 44. We have pointed out before (*vide supra*, i-9-14) that the mean longitude of the *śīghrocca*, in the case of Mercury and Venus, is the heliocentric mean longitude of the planet. The true heliocentric longitude may be obtained by applying the planet's *mandaphala* correction to that. The true longitude obtained above is the true geocentric longitude.

above. Multiply that by the radius and divide the product by the *śīghra-karṇa* which is obtained by formula (2) above. Then find the corresponding arc, and add that to or subtract that from the true-mean longitude of the planet, according as the *śīghrakendra* is less or greater than 180°. The result thus obtained is the true longitude of the planet for true sunrise at the local place.

Criterion for knowing whether a planet is stationary :

40. When (the longitude of) a planet for today is equal to that for tomorrow, then is said to be the commencement or conclusion of the retrograde motion of that planet.

A rule for finding the amounts of the retrograde and direct motions of a planet :

41. (Whatever is obtained on) subtracting the longitude (of a planet) for tomorrow from the longitude for today (when it is possible), is called the retrograde motion (of the planet for the day); and whatever results on performing the subtraction reversely gives the direct motion (of the planet for the day).

The commentator Śaṅkaranārāyaṇa interprets the text as follows :

"When the longitude of a planet calculated for tomorrow is less than the longitude for today, the motion (of the planet) is said to be retrograde; when it is the contrary, the motion is direct."

CHAPTER III

DIRECTION, PLACE AND TIME FROM SHADOW

Determination of the directions with the help of the shadow of a gnomon:

1. The north and south directions should be determined by means of the fish-figure constructed with the two points where the end of the shadow of the gnomon, situated at the centre of an arbitrary circle (drawn on the ground) meets that circle (in the forenoon and in the afternoon).[1]

Let ENWS (See Fig. 3) be the circle drawn on the ground, and O its centre where the gnomon is situated. Let W_1 be the point where the shadow of the gnomon enters into the circle in the forenoon and E_1 the point where the shadow passes out of the circle in the afternoon. Then W and E_1 are

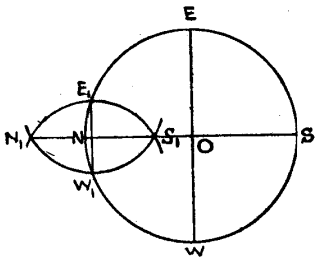

Fig. 3

the points where the end of the shadow of the gnomon meets the circle in the forenoon and afternoon respectively. Join E_1W_1. The line E_1W_1 is directed east to west. With E_1 as centre and with a radius greater than $\frac{1}{2}E_1W_1$ draw an arc of a circle, and with W_1 as centre and with the same radius draw another arc cutting the former at the points N_1 and S_1. Join N_1 and S_1. The line N_1S_1 is directed north to south. Let the line N_1S_1 meet the circle in the points N and S and the line through O drawn parallel to E_1W_1 in E and W. Then E, W, N and S are respectively the east, west, north and south directions with respect to the point O.

---

[1] Cf. *MBh*, iii. 1-2.

The figure $N_1E_1S_1W_1N_1$ which looks like a fish has been called a "fish-figure".

Also see my notes on *MBh*, iii. 1, 2.

A rule for finding the latitude and colatitude of a place from the equinoctial midday shadow of the gnomon:

2-3. By whatever results as the square root of the sum of (1) the square of the equinoctial midday shadow of the gnomon, which is erected on level ground at the intersection of the direction-lines[1] and whose perpendicularity has been tested, and (ii) the square of the gnomon, divide the radius (severally) multiplied by the gnomon and the (equinoctial midday) shadow: the results are the Rsines of the colatitude and the latitude.[2]

That is, if R be the radius of the celestial sphere, g the length of the gnomon, and s the length of the equinoctial midday shadow, ϕ the latitude of the place, and $C(=90°-\phi)$ the colatitude, then

$$\text{Rsin } C = \frac{g \times R}{\sqrt{(g^2+s^2)}}, \qquad (1)$$

$$\text{and Rsin } \phi = \frac{s \times R}{\sqrt{(g^2+s^2)}}, \qquad (2)$$

Fig. 4 is the celestial sphere for a place in latitude ϕ. SENW is the horizon, S, E, N and W being the south, east, north and west points; Z is the

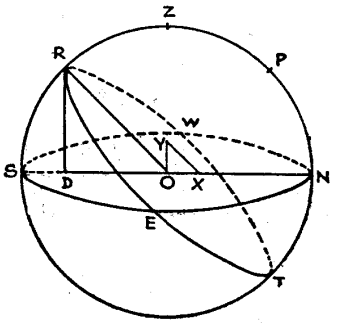

Fig. 4

[1] i.e., at the centre of the circle drawn on the ground. See stanza 1.

[2] Cf. *MBh*, iii. 4-5(i-iii).

zenith. RETW the equator, and P the north pole. R is the point where the equator intersects the local meridian. Then the arc ZR defines the latitude of the place.

OY is the gnomon erected at the local place O perpendicular to the plane of the horizon. Let RD be perpendicular to the plane of the horizon and YX parallel to RO. Then we have two right-angled triangles YOX and RDO, right angled at O and D respectively. These triangles are similar and their corresponding sides are as follows:

base	upright	hypotennse
DO(=Rsinϕ)	RD=(Rsin C)	RO(=R)
OX(=s)	YO(=g)	YX(=$\sqrt{g^2+s^2}$)

Comparing these triangles, we have (1) and (2).

A rule for finding the ascensional differences of the tropical signs Aries, Taurus, and Gemini:

4. From the declinations of the last points of the (first three) signs should be obtained, as before,[1] their ascensional differences in terms of *asus*. When (each of them is) diminished by the preceding (ascensional difference, if any,) they become (the *asus* of ascensional difference) for Aries, Taurus, and Gemini respectively.

That is, if x, y, and z be the ascensional differences of the last points of the signs Aries, Taurus, and Gemini respectively, then the ascensional differences of the signs Aries, Taurus, and Gemini are x, $y-x$, $z-y$ respectively.

We have already seen that the ascensional difference of the Sun is the difference between the times of rising of the Sun on the local and equatorial horizons. The ascensional difference of the sign Aries is the difference between the times of its rising above the local and equatorial horizons. Since the first point of Aries rises simultaneously at both the horizons, therefore the ascensional difference of Aries is equal to the ascensional difference of the last point of Aries (for which the celestial longitude λ is equal to 30°). Similarly, the ascensional difference of Aries and Taurus (taken together) is equal to the ascensional difference of the last point of Taurus (for which $\lambda=60°$).

[1] *Vide supra*, Chapter II, stanza 18.

The ascensional difference of Taurus is equal to the ascensional difference of Aries and Taurus minus the ascensional difference of Aries. That is to say, it is equal to the ascensional difference of the last point of Taurus minus the ascensional difference of the last point of Aries.

The ascensional difference of Gemini, similarly, is equal to the ascensional difference of the last point of Gemini minus the ascensional difference of the last point of Taurus.

The times of rising of Aries, Taurus, and Gemini at the equator:

5. 1670, 1795 and 1935 are (in *asus*) the times of rising of (the first three tropical signs) Aries etc., at Laṅkā.[1]

It can be easily seen from the celestial sphere that the time of rising of Aries at the equator is equal to the right ascension of the last point of Aries, and the time of rising of Aries and Taurus (taken together), equal to the right ascension of the last point of Taurus. Thus the time of rising of Taurus is equal to the right ascension of the last point of Taurus minus the right ascension of the last point of Aries. Similarly, the time of rising of Gemini at the equator is equal to the right ascension of the last point of Gemini minus the right ascension of the last point of Taurus.

Now from *MBh*, iii. 9, we have

$$\text{Rsin } \alpha = \frac{3141 \times \text{Rsin}\lambda}{\text{Rcos } \delta} \text{ asus}, \tag{1}$$

where α is the right ascension of a point on the ecliptic, λ its tropical longitude and δ its declination.

Also from ii. 16 above

$$\text{Rsin } \delta = \frac{1397' \times \text{Rsin}\lambda}{R}. \tag{2}$$

Therefore

$$\text{Rsin } \alpha = \frac{3141 \times \text{Rsin}\lambda}{\sqrt{[R^2 - \{1397' \times \text{Rsin}\lambda/R\}^2]}}. \tag{3}$$

Putting $\lambda = 30°$, 60° and 90° successively in (3), we easily get $\alpha = 1670$ *asus*, 3465 *asus*, and 5400 *asus* approx.

Hence the times of rising of Aries, Taurus and Gemini at the equator are

[1] Cf. *MBh*, iii. 10(i).

1670 *asus*, (3465—1670) *asus*, and (5400—3465) *asus*

i.e., 1670 *asus*, 1795 *asus*, and 1935 *asus*

respectively.

A rule for the determination of the times of rising of the tropical signs at the local place :

6. (From the above times of rising of Aries, Taurus, and Gemini at Laṅkā should be subtracted the *asus* of their (own) ascensional differences, in order, and (then) (to the same times of rising of Aries, Taurus, and Gemini at Laṅkā) they should be added in the reverse order : the results (in order) are the times (in *asus*) of rising at the local place of the tropical signs beginning with Aries, and (the same results) in the reverse order (are for those) beginning with Libra.[1]

If a, b, c denote the ascensional differences of Aries, Taurus and Gemini respectively, then the times of rising of the signs at the local place are as given in the following table.

Times of Rising of the Signs at the Local Place

Sign	Time of rising at the local place in *asus*	Sign
1. Aries	$1670-a$	12. Pisces
2. Taurus	$1795-b$	11. Aquarius
3. Gemini	$1935-c$	10. Capricorn
4. Cancer	$1935+c$	9. Sagittarius
5. Leo	$1795+b$	8. Scorpio
6. Virgo	$1670+a$	7. Libra

From what has been said above, we have

Time of rising of a sign at the local place

= time of rising of the sign at the equator

− {(ascensional difference of the last point of the sign)

− (ascensional difference of the first point of the sign)}.

[1] Cf. *MBh*, iii. 10(ii).

Hence the above rule.

The following table gives the times of rising in *asus* of the tropical signs at Lucknow.

Sign	Time of Rising in *asus* at Lucknow	Sign
1. Aries	1670−354=1316	12. Pisces
2. Taurus	1795−290=1505	11. Aquarius
3. Gemini	1935−119=1816	10. Capricorn
4. Cancer	1935+119=2054	9. Sagittarius
5. Leo	1795+290=2085	8. Scorpio
6. Virgo	1670+354−2024	7. Libra

A rule for finding the Rsine of the Sun's zenith distance and the length of the shadow of the gnomon from the time elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon and the Sun's declination :

7-10. The *ghaṭīs* elapsed (since sunrise) and to be elapsed (before sunset), in the first half and the other half of the day (respectively), should be multiplied by 60 and again by 6 : then they (i.e., those *ghaṭīs*) are reduced to *asus*. (When the Sun is) in the northern hemisphere, the *asus* of the Sun's ascensional difference should be subtracted from them and (when the Sun is) in the southern hemisphere, they should be added to them. (Then) calculate the Rsine (of the resulting difference or sum) and multiply that by the day-radius. Then dividing that (product) by the radius, operate (on the quotient) with the earth-sine contrarily to that above (i.e., add or subtract the earth-sine according as the Sun is in the northern or southern hemisphere). Multiply that (sum or difference) by the Rsine of the colatitude and divide by the radius : the result is the Rsine of the Sun's altitude. The square root of the difference between the squares of that and of the radius is the Rsine of the Sun's zenith distance. That multiplied by twelve and divided by the Rsine of the Sun's altitude is the true shadow (of the gnomon).[1]

[1] Cf. *MBh*, iii. 18-20.

The *ghaṭīs* elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon, being multiplied by 60 and again by 6, give the minutes of arc in the arc of the celestial equator lying between the hour circles passing through the Sun at that time and through the Sun's position on the horizon at sunrise or sunset. When these *asus* are diminished or increased by the *asus* of the Sun's ascensional difference (according as the Sun is in the northern or southern hemisphere), the *asus* of the difference or sum give the minutes of arc in the arc of the celestial equator lying between the Sun's hour circle and the six o'clock circle. The Rsine of that difference or sum multiplied by the day-radius and divided by the radius gives the distance of the Sun from the line joining the points of intersection of the six o'clock circle and the Sun's diurnal circle. This increased or diminished by the earthsine (according as the Sun is in the northern or southern hemisphere) gives the distance of the Sun from the Sun's rising - setting line (i.e., the line joining the points of the horizon where the Sun rises and sets).

In Fig. 5 let S denote the position of the Sun on the celestial sphere, SA the perpendicular from S on the plane of the celestial horizon, and SB the perpendicular from S on the rising-setting line. Then in the plane triangle SAB, we have

$$SA = R\sin a,$$

$$SB = \frac{R\sin(\text{given time in } asus \mp \text{asc. diff.}) \times \text{day radius}}{R} \pm \text{earthsine},$$

$$\angle SBA = 90° - \phi,$$

and $\angle SAB = 90°$,

where a is the Sun's altitude, and ϕ the latitude of the place.

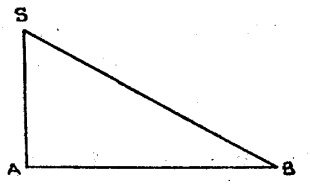

Fig. 5

Therefore, we have

$$R\sin a = \frac{SB \times R\cos\phi}{R}.$$

Also since the Sun's zenith distance z is the complement of a, therefore

$$R\sin z = R\cos a = \sqrt{\{R^2 - (R\sin a)^2\}}.$$

Now the triangle of shadow for that time in which
base=shadow of the gnomon,
upright=length of the gnomon,
and hypotenuse=hypotenuse of shadow,
is similar to the triangle of the great shadow in which
base = Rsin y,
upright= Rsin a,
and hypotenuse = R.

Hence comparing the bases and uprights of the two triangles, we have

$$\text{shadow of the gnomon} = \frac{\text{Rsin } z \times \text{length of the gnomon}}{\text{Rsin } a}$$

$$= \frac{\text{Rsin } z \times 12}{\text{Rsin } a},$$

taking length of gnomon=12 *angulas*.

If instead of the time elapsed since sunrise or to elapse before sunset, the longitudes of the Sun and of the rising point of the ecliptic be known, then the time elapsed since sunrise or to elapse before sunset may be determined by the following formula :

time elapsed since sunrise
=time of rising at the local place of the arc of the ecliptic lying between the Sun and the rising point of the ecliptic;

time to elapse before sunset
=duration of the day—time elapsed since sunrise
=(30 *ghaṭīs*±twice the Sun's ascensional difference)
— time elapsed since sunrise,

+or — sign being taken according as the Sun is in the northern or southern hemisphere.

Two particular cases of the above rule, viz. (i) when the Sun's ascensional difference is greater than the given time, and (ii) when the Sun is below the horizon :

11. When the Sun's ascensional difference cannot be subtracted from the given (time in) *asus*, reverse the subtraction (i.e., subtract the latter from the former) and with the Rsine of the remainder (proceed as above).[1] In the night the Rsine of

[1] Cf. *MBh*, iii. 25.

the Sun's altitude should be obtained contrarily (i.e., by reversing the laws of addition and subtraction).[1]

The first part of the rule relates to the case when the Sun is in the northern hemisphere and lies between the local and equatorial horizons, i.e., shortly after sunrise or before sunset.

The second part of the rule indicates the method to be used for finding the Sun's altitude in the night. The details of the method are given by the commentator Parameśvara as follows :

"(When the Sun is) in the northern hemisphere, having calculated the Rsine of the given nocturnal *asus* (i.e., those elapsed since sunset in the first half of the night or those to elapse before sunrise in the second half of the night) as increased by the (Sun's) ascensional difference, (then) multiplying (that) by the day-radius and dividing by the radius, then from the (resulting) quotient subtracting the earthsine, and (finally) multiplying the remainder by the Rsine of the colatitude and dividing by the radius is obtained the Rsine of the Sun's altitude. (When the Sun is) in the southern hemisphere, the (Sun's) ascensional difference and the earthsine are (respectively) subtractive and additive : this is the difference."

The Rsine of the Sun's altitude in the night is required (1) in the calculation of the elevation of the lunar horns, and (2) in the calculation of the solar eclipse.

A rule for calculating the time elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon with the help of the shadow of the gnomon :

12-15. By the divisor, which is the square root of the sum of the squares of the gnomon and its shadow, should be divided the radius multiplied by the gnomon: (the result is) the Rsine of the Sun's altitude. From that are obtained the *ghaṭis* (of the time elapsed since sunrise in the forenoon or to elapse before sunset in the afternoon) (by proceeding) conversely (to Rule 7-10) (in the following manner):

The Rsine of the Sun's altitude should be multiplied by the radius and divided by the Rsine of the colatitude. In the

[1] Cf. *MBh*, iii. 26.

(resulting) quotient should be subtracted or added the earthsine according as the Sun is in the northern or southern hemisphere. Then having multiplied that (result) by the radius and divided by the day-radius, to the arc of the (resulting) quotient add or subtract from the same arc the *asus* of the (Sun's) ascensional difference (according as the Sun is) in the northern or southern hemisphere. (Dividing the resulting *asus*) by 6 and again by 60 should be determined the *ghaṭīs* elapsed (since sunrise) and to elapse (before sunset) in the first half and the second half of the day (respectively).[1]

This rule is the converse of that given in stanzas 7-10 above.

A rule for the calculation of the Sun's *saṅkvagra* :

16. The Rsine of the Sun's altitude multiplied by the Rsine of the latitude and divided by the Rsine of the colatitude is the (Sun's) *śaṅkvagra,* which is always to the south of the rising-setting line.[2]

The Sun's *śaṅkvagra* denotes the distance of the Sun's projection from the (sun's) rising-setting line.

In Fig. 6, S denotes the Sun, A the foot of the perpendicular dropped from the Sun on the plane of the celestial horizon, SB the perpendicular from S on the rising-setting line, and AB the perpendicular from A on the rising-setting line. So AB is evidently the *śaṅkvagra*.

Since

$$SA = \text{Rsin } a,$$
$$AB = \textit{śaṅkvagra},$$
$$\angle SBA = 90 - \phi,$$
$$\angle ASB = \phi,$$

therefore, we have

$$\frac{AB}{\text{Rsin } (\angle ASB)} = \frac{SA}{\text{Rsin } (\angle SBA)}$$

giving

$$\textit{śaṅkvagra} = \frac{\text{Rsin } a \times \text{Rsin } \phi}{\text{Rcos } \phi}.$$

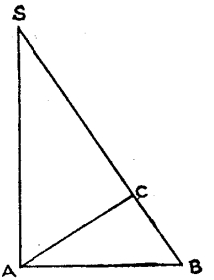

Fig. 6

[1] Cf. *MBh*, iii. 27-28(i).

[2] Cf. *MBh*, iii. 54.

It can be easily seen from the celestial sphere that, whatever be the position of the Sun, the *śaṅkvagra* will always lie to the south of the rising-setting line.

A rule for the determination of the tropical longitude of the rising point of the ecliptic at any given time with the help of the time elapsed since sunrise and the correspondng tropical longitude of the Sun:

17-19. The residue (i.e., the untraversed portion) of the Sun's (tropical) sign (in minutes of arc) should be multiplied by the time of its rising at the local place and divided by the number of minutes in a sign (i.e., 1800): the result should be subtracted from the given (time elapsed since sunrise, in) *asus*. (Then) having added the residue of the (Sun's) sign to (the tropical longitude of) the Sun, one should (further) add successively the (subsequent) signs whose times of rising, in *asus*, at the local place can be subtracted from the remaining (time in) *asus*. That (further) increased by the degrees and minutes obtained on multiplying the remainder (in *asus*) by 30, etc., and dividing by the time of rising at the local place of the (tropical) sign occupied by the rising point of the ecliptic should be declared as the (tropical) longitude of the rising point of the ecliptic.[1]

We shall illustrate this rule by an example. Suppose that 14 *ghaṭīs* after sunrise at Lucknow (lat. 26° 55′ E, long. 80° 45′ E.) the tropical longitude of the Sun is $3^s\,4°\,20'$. Then to find the longitude of the rising point of the ecliptic we shall proceed as follows:

The Sun lies in the 4th sign, the untraversed portion of that sign being 25° 10′ (=1510′). The time of rising of this sign at Lucknow is 2054 *asus*. (See the table of times of risings of signs at Lucknow on page 46). Therefore, we multiply 1510′ by 2054 and divide the product by 1800; thus we get

$$\frac{1510 \times 2054}{1800} = 172 \quad \textit{asus} \text{ approx.}$$

This is the time of rising of the untraversed portion of the Sun's sign.

Subtracting this from 14 *ghaṭīs*, i.e., 5040 *asus*, we get 3317 *asus*. Subtracting from this the *asus* of rising of the 5th sign, i.e., 2085 *asus*, we get 232 *asus*. The *asus* of rising of the 6th sign cannot be subtracted from it, so we

[1] Cf. *MBh*, iii. 30-32.

multiply this by 1800 and divide the product by the *asus* of rising of the 6th sign, i.e , by 2024. Thus we get

$$\frac{232\times1800}{2024}=202' \text{ or } 3°22' \text{ approx.}$$

Thus we see that in 14 *ghaṭīs* 25°10′ of the 4th sign, the whole of the 5th sign and 3°22′ of the sixth sign have risen above the horizon of Lucknow. Adding these to the Sun's longitude, we get $5^s\,3°\,22'$ as the tropical longitude of the rising point of the ecliptic.

A rule for obtaining the time elapsed since sunrise with the help of the tropical longitude of the rising point of the ecliptic and the tropical longitude of the Sun :

20. One who desires to know the time (elapsed after sunrise) obtains that time on adding together, in the reverse order, the times of rising at the local place of the signs (and parts thereof, if any) traversed by the horizon-ecliptic point up to the untraversed portion of the Sun's (tropical) sign.[1]

This rule is the converse of the preceding one.

A rule for calculating (the Rsine of) the Sun's *agrā*:

21. The result obtained on dividing the Rsine of the *bhujā* of the Sun's (tropical) longitude as multiplied by the Rsine of the Sun's greatest declination, by the Rsine of the cōlatitude is known as (the Rsine of) the Sun's *agrā*.[2]

That is,

$$\text{Rsin (Sun's } agr\bar{a}) = \frac{\text{Rsin } (bhuj\bar{a}\ \lambda)\times\text{Rsin}\epsilon}{\text{Rsin } (90-\phi)},$$

where λ is the Sun's (tropical) longitude, ϵ the Sun's greatest declination (i. e., the obliquity of the ecliptic), and ϕ the latitude of the local place. [For the *rationale* of this formula, see under stanzas 22-23 below.]

The term *agrā*, in Hindu astronomy, has been used in two senses :

(i) The arc of the celestial horizon lying between the east point and the point where the heavenly body concerned rises.

[1] Cf. *MBh*, iii. 34-36.

[2] Cf. *MBh*, iii. 37.

(ii) The Rsine of that arc, which is equal to the distance between the east-west line and the rising-setting line of the heavenly body concerned.

To avoid this ambiquity, we have translated the term *agrā* by "(the arc of) *agrā*" or "(the Rsine of) *agrā*", according as it is used in the former or latter sense. Whenever the qualifying phrases have not been used the meaning should be understood from the context.

A rule for calculating the prime vertical altitude of the Sun and the corresponding shadow of the gnomon:

22-23. The Rsine of the Sun's northern declination, when less than the Rsine of the latitude, multiplied by the radius should be divided by the Rsine of the latitude: the result is the Rsine of the altitude of the Sun when it is on the prime vertical. The square root of the square of the radius diminished by that of the Rsine of the Sun's altitude (obtained above) when multiplied by twelve and divided by the (same) Rsine of the Sun's altitude gives the shadow (of the gnomon corresponding to the Sun on the prime vertical).[1]

That is, when the Sun is on the prime vertical,

$$\text{(i)} \quad \text{Rsin } a = \frac{\text{Rsin } \delta \times R}{\text{Rsin } \phi},$$

(ii) Shadow of the gnomon

$$= \frac{12}{\text{Rsin } a}[R^2 - (\text{Rsin } a)^2]^{1/2},$$

where a is the Sun's altitude, δ the Sun's declination, and ϕ the latitude of the place.

In Fig. 6 on page 50, let S denote the position of the Sun when it is on the prime vertical, SA and SB the perpendiculars from S on the east-west and rising-setting lines respectively, and C the point where SB meets the line joining the points of intersection of the Sun's diurnal circle and the six o'clock circle. Since SB lies in the plane of the diurnal circle and AC in the plane of the six o'clock circle, and the two circles are at right angles, therefore AC and SB are at right angles.

[1] Cf. *MBh*, iii. 37-38.

In the triangle ABC, we have

$$AC = R\sin\delta,$$

$$AB = R\sin(\text{Sun's } agr\bar{a}),$$

$$\angle ABC = 90° - \phi,$$

$$\text{and } \angle ACB = 90°,$$

where δ is the Sun's declination, and ϕ the latitude of the place.

Therefore,

$$R\sin(\text{Sun's } agr\bar{a}) = \frac{R\sin\delta \times R}{R\cos\phi}. \qquad (1)$$

But, from ii. 16,

$$R\sin\delta = \frac{R\sin(bhuj\bar{a}\lambda) \times R\sin\epsilon}{R}.$$

Therefore

$$R\sin(\text{Sun's } agr\bar{a}) = \frac{R\sin(bhuj\bar{a}\lambda) \times R\sin\epsilon}{R\cos\phi}$$

where λ is the Sun's tropical longitude. [See rule 21 above.]

Now in the triangle SAB, right-angled at A, we have

$$SA = R\sin a,$$

$$AB = R\sin(\text{Sun's } agr\bar{a}),$$

$$\text{and } \angle SBA = 90° - \phi.$$

Therefore

$$R\sin a = \frac{R\sin(\text{Sun's } agr\bar{a}) \times R\cos\phi}{R\sin\phi}$$

$$= \frac{R\sin\delta \times R}{R\sin\phi}, \text{ using (1)}, \qquad (2)$$

where a is the Sun's altitude.

This formula can also be derived directly by considering the triangle SAC.

The formula for the shadow of the gnomon easily follows from the shadow triangle.

The condition that "the Rsine of the Sun's northern declination should be less than the Rsine of the latitude" is necessary for the existence of

the prime vertical shadow of the gnomon. When this condition is not satisfied, the Sun in the northern hemisphere would not cross the prime vertical and likewise the prime vertical shadow of the gnomon would not exist. When the Sun is in the southern hemisphere, the Sun does not cross the prime vertical above the horizon and so the prime vertical shadow of the gnomon does not exist.

A rule for the determination of the Sun's tropical longitude from the Sun's prime vertical altitude :

24-25. The Rsine of the Sun's altitude (when the Sun is on the prime vertical), determined from the method of the shadow,[1] should be multiplied by the Rsine of the latitude and divided by the Rsine of the (Sun's) greatest declination: the resulting Rsine, in minutes of arc, reduced to arc or that subtracted from half a circle (i.e., 180°) is known as the (tropical) longitude of the Sun determined from the shadow of the gnomon when the Sun is on the prime vertical (according as the Sun is in the first or second quadrant, i.e. according as the prime vertical shadow or midday shadow of the gnomon is decreasing or increasing day to day).[2]

This rule follows from the previous one combined with rule ii. 16.

A rule for finding the arc corresponding to a given Rsine :

26. The number of the tabulated Rsine-differences which can be subtracted from the given Rsine, as also the remainder (of that subtraction, if any) divided by the current (i.e., next) Rsine-difference, should be (severally) multiplied by 225: their sum is the (required) arc.[3]

This rule is the converse of that given in ii. 2(ii)-3(i) above. It has been stated here because it is required in the preceding rule for calculating the arc corresponding to the Rsine of the Sun's longitude.

A rule for finding the midday shadow of the gnomon with the help of the Sun's declination and the latitude of the place:

27-28. In case the Sun is situated on the meridian (lit. in

[1] See stanza 12 above.

[2] Cf *MBh*, iii, 41.

[3] Cf. *MBh*, viii. 6.

the middle of the sky), the Rsine of the sum or difference of the arcs of the latitude and the (Sun's) declination according as the Sun is in the southern or northern hemisphere, is the (great) shadow. Whatever is the square root of the number which is obtained on subtracting the square of that from the square of the radius is the (great) gnomon. The shadow of the gnomon of twelve (*aṅgulas*) should be determined by proportion.[1]

The great shadow is the Rsine of the Sun's zenith distance, and the great gnomon is the Rsine of the Sun's altitude.

When the great shadow and the great gnomon are known, the shadow of the gnomon of twelve *aṅgulas* is obtained by the formula:

$$\text{shadow of the gnomon} = \frac{\text{great shadow} \times 12}{\text{great gnomon}}.$$

A rule for the determination of the Sun's longitude from the midday shadow of the gnomon:

29-33. The square root of the sum of the squares of the gnomon and its midday shadow is the divisor of the product of the (midday) shadow and the radius: the resulting quotient is the Rsine of the (Sun's) meridian zenith distance.

(When the midday shadow falls) towards the north, the Sun's meridian zenith distance, if less than the latitude, should be subtracted from the latitude; when the (midday) shadow falls towards the south, take their sum: the result (in both cases) is the (Sun's northern) declination.[2] In the contrary case (i.e., when the midday shadow falls towards the north but the Sun's meridian zenith distance is greater than the latitude), the latitude should be subtracted from the (Sun's) meridian zenith distance : the (resulting) remainder is the Sun's southern declination.[3] The Rsine of that (i.e., the Sun's declination, north or south) should be multiplied by the radius and divided by the (Sun's) greatest declination: the arc corresponding to the quotient or that

[1] Cf. *MBh*, iii. 11.
[2] Cf. *MBh*, iii. 13-14.

subtracted from half a circle (i.e., 180°) is known as (the tropical longitude of) the Sun (according as the Sun is in the first quadrant beginning with the tropical sign Aries or in the second quadrant beginning with the tropical sign Cancer, i.e., according as the midday shadow, if falling towards the north, is decreasing or increasing day to day, and, if falling towards the south, is increasing or decreasing day to day). This method is for (the Sun in) the northern hemisphere. Now we describe the method for (the Sun in) the southern hemisphere. (There) the arc (obtained above) should be added to half a circle or subtracted from 12 (signs) (i.e , from 360°) (according as the Sun is in the third quadrant beginning with the tropical sign Libra or in the fourth quadrant beginning with the tropical sign Copricorn, i.e., according as the midday shadow falling towards the north is increasing or decreasing day to day).[1]

A consolidated rule for finding the Sun's declination with the help of the Sun's meridian zenith distance and the latitude :

34. The sum or difference of the meridian zenith distance and the latitude, according as the (midday) shadow of the gnomon falls towards the south or towards the north, is known as declination.

A rule for finding the local latitude with the help of the meridian zenith distance and declination of the Sun and the direction of the midday shadow of the gnomon :

35. When the Sun is in the northern hemisphere, the (meridian) zenith distance and the declination of the Sun should be added together (if the midday shadow of the gnomon falls towards the north). In the contrary case (viz. when the Sun is in the southern hemisphere), or when the (midday) shadow falls in the contrary direction (i.e., towards the south), one should take their difference. The result (in each case) is the latitude.[2]

[1] Cf. *MBh*, iii. 16,
[2] Cf. *MBh*, iii. 17.

CHAPTER IV

THE LUNAR ECLIPSE

A rule for the determination of the longitudes of the Sun and the Moon when they are in opposition or conjunction in longitude :

1. One who wants to obtain (the longitudes of the Sun and the Moon when there is) equality in minutes of arc[1] should add as many minutes of arc as there are *parvanāḍīs*, to the Sun's longitude (at sunrise) and the same together with the minutes of arc (of the difference between the longitude of the Sun as increased by 6 signs, and the longitude of the Moon in the case of opposition, or of the difference between the longitudes of the Sun and the Moon in the case of conjunction) to the Moon's longitude (when opposition or conjunction of the Sun and Moon is to occur); similarly, (when opposition or conjunction of the Sun and Moon has occurred) one should subtract the *pratipad-nāḍīs* (etc. from the longitudes of the Sun and the Moon).

In other words, if S and M denote the longitudes of the Sun and the Moon at sunrise on the full moon day, then

Sun's longitude at the time of opposition of the Sun and Moon
$= S +$ *parvanāḍīs* treated as minutes of arc;

and Moon's longitude at the time of opposition of the Sun and Moon
$= M +$ *parvanāḍīs* treated as minutes of arc
$+ (S + 6 \text{ signs} - M)$;

and if S' and M' denote the longitudes of the Sun and the Moon at sunrise on the new moon day, then

Sun's longitude at the time of conjunction of the Sun and Moon
$= S' +$ *parvanāḍīs* treated as minutes of arc,

[1] When the Sun and Moon are in opposition, their longitudes differ by six signs; when they are in conjunction, their longitudes are the same. The minutes, however, are the same. The equality in minutes of arc refers here to the time of opposition or conjunction.

and Moon's longitude at the time of conjunction of the Sun and Moon

$= M' + parvan\bar{a}d\bar{\imath}s$ treated as minutes of arc $+ (S' - M')$.

If S_1 and M_1 denote the longitudes of the Sun and the Moon at sunrise on the day following full moon, then

Sun's longitude at the time of opposition of the Sun and Moon

$= S_1 - pratipad\text{-}n\bar{a}d\bar{\imath}s$ treated as minutes of arc,

and Moon's longitude at the time of opposition of the Sun and Moon

$= M_1 - pratipad\text{-}n\bar{a}d\bar{\imath}s$ treated as minutes of arc

$- [M_1 - (S_1 + 6 \text{ signs})]$;

and if S_1' and M_1' denote the longitudes of the Sun and the Moon at sunrise on the day following new moon, then

Sun's longitude at the time of conjunction of the Sun and Moon

$= S_1' - pratipad\text{-}n\bar{a}d\bar{\imath}s$ treated as minutes of arc,

and Moon's longitude at the time of conjunction of the Sun and Moon

$= M_1' - pratipad\text{-}n\bar{a}d\bar{\imath}s$ treated as minutes of arc

$- (M_1' - S_1')$.

By *parvanāḍīs* is meant "the *nāḍīs* of the full moon or new moon *tithi* (called *parva*) which are to elapse at sunrise on that day". Similarly, by *pratipad-nāḍīs* is meant "the *nāḍīs* of the next *tithi* (called *pratipad* or *pratipadā*) which elapse at sunrise on that day."

The above rule gives only an approximate result because it is based on the assumption that the Sun travels at the rate of one minute of arc per *nāḍī*, but for practical purposes it is good enough.

Mean distances of the Sun and the Moon in terms of *yojanas* :

2. 459585 is (in *yojanas*) the (mean) distance of the Sun and 34377 that of the Moon.[1]

A rule for finding the true distances of the Sun and the Moon in terms of *yojanas* :

3. These (above-mentioned mean distances of the Sun and the Moon) multiplied by their true distances in minutes

[1] The same distances are given in *MBh*, v. 2; and *ŚiDV*$_{\text{r}}$, I, iv. 4.

obtained by the method of successive approximations[1] and divided by the radius (i.e., by 3438′) give their true distances in *yojanas*.[2]

That is,

Sun's true distance in *yojanas*

$$= \frac{\text{Sun's mean distance in } yojanas \times \text{Sun's true distance in minutes}}{3438'}$$

and Moon's true distance in *yojanas*

$$= \frac{\text{Moon's mean distance in } yojanas \times \text{Moon's true distance in minutes}}{3438'}$$

Diameters of the Sun, the Moon and the Earth :

4. The diameter of the Sun is 4410 (*yojanas*); of the Moon, 315 (*yojanas*); and of the Earth, 1050 (*yojanas*).[3]

A rule for finding the angular diameters of the Sun and the Moon :

5. Multiply the radius (i.e., 3438′) (separately) by their diameters in *yojanas* and divide by their true distances in *yojanas*: then are obtained their true (i.e., angular) diameters in minutes of arc.[4]

That is,

Sun's diameter in minutes of arc

$$= \frac{\text{Sun's diameter in } yojanas \times 3438'}{\text{Sun's true distance in } yojanas},$$

and Moon's diameter in minutes of arc

$$= \frac{\text{Moon's diameter in } yojanas \times 3438'}{\text{Moon's true distance in } yojanas}.$$

---

[1] See *supra*, ii. 7.

[2] The same rule is given in *MBh*, v. 3; *ŚiDVṛ*, I, iv. 5(i); *SiŚe*, v. 4 (ii); *SiŚi*, I, v. 5(i); and *TS*, iv. 10(ii)-11.

[3] The same values are given in *MBh*, v. 4; *ŚiDVṛ*, I, iv. 6 (i); and *TS*, iv. 10(i).

[4] Cf. *MBh*, v. 5.

A rule for the determination of the length of the Earth's shadow :

6. Multiply the Sun's (true) distance (in *yojanas*) by the diameter of the Earth in *yojanas* and divide by the difference between (the diameters of) the Sun and the Earth. Then is obtained (in *yojanas*) the length of the Earth's shadow.[1]

That is,

length of the Earth's shadow

$$= \frac{\text{Sun's true distance in } yojanas \times \text{Earth's diameter}}{\text{Sun's diameter} - \text{Earth's diameter}}.$$

By "the length of the Earth's shadow" is meant "the distance of the vertex of the Earth's shadow from the Earth's centre".

A rule for the determination of the diameter of the Earth's shadow at the point where the Moon crosses it, in terms of minutes :

7. This (length of the Earth's shadow) diminished by the (true) distance of the Moon and multiplied by the diameter of the Earth and (then) divided by the length of the Earth's shadow gives (in *yojanas*) the diameter of the Earth's shadow (at the point where the Moon crosses it). This should be reduced to minutes of arc like (the diameter of) the Moon.[2]

That is,

Diameter of the Earth's shadow

$$= \frac{(\text{length of Earth's shadow} - \text{Moon's true distance})\ \text{Earth's diameter}}{\text{length of Earth's shadow}}$$

yojanas

By "the diameter of the Earth's shadow" we mean "the diameter of the section of the Earth's shadow cone where the Moon crosses it at the time of the first or last contact".

For the Hindu method of deriving the formulae of stanzas 6 and 7, see my notes on *MBh*, v. 71-73.

[1] Cf. *MBh*, v. 71.
MBh, v. 72(ii)-73.

A rule for finding the Moon's latitude :

8. Multiply the Rsine of the difference between the longitudes of the Moon, when in opposition with the Sun, and its ascending node by 270 and divide (the product) by the true distance of the Moon, in minutes : the result is the Moon's (true) latitude, north or south.[1]

That is,

Moon's latitude in minutes of arc

$$= \frac{\text{Rsin}\,(\text{M} - ☊) \times 270'}{\text{Moon's true distance in minutes}} \quad \text{approx.},$$

where M, ☊ denote the longitudes of the Moon and Moon's ascending node.

This formula is evidently wrong and has been discarded by later astronomers. The correct formula is

Moon's latitude in minutes

$$= \frac{\text{Rsin}\,(\text{M} - ☊) \times 270'}{\text{R}} \quad \text{approx.}$$

A rule for finding the measure of the Moon's diameter unobscured by the shadow :

9. Diminishing the (minutes of arc of the) Moon's latitude (obtained above) by half of the minutes of arc resulting on diminishing the diameter of the shadow by that of the Moon are obtained those of (the diameter of) the Moon which remain unobscured by the shadow.[2]

It is easy to see that the obscured part of the Moon's diameter (at the time of opposition in the case of a partial lunar eclipse)

$= \frac{1}{2}$ (diameter of shadow + Moon's diameter) − Moon's latitude, and hence the unobscured part of the Moon's diameter at that time

= Moon's latitude − $\frac{1}{2}$ (diameter of the shadow − Moon's diameter).

Bhāskara I does not make any distinction between the time of opposition and the time of the middle of the eclipse. Hence the above rule.

[1] Cf. *MBh*, v. 30-31(i). This rule occurs also in *TS*, iv. 17(ii)-18(i).

[2] This rule occurs also in *Ā*, iv. 43; *ŚiDVṛ*, I, iv. 13; *SiŚe*, v. 11; *MSi*, v. 7; *TS*, iv. 19(ii)-20(i). Also see *SūSi*, iv. 10; *BrSpSi*, iv. 7; *SiŚi*, I, v. 11.

A rule relating to the calculation of the *sparśa-* and *mokṣa-sthityardhas* :

10-12. Diminish the square of half the sum of the diameters of the Moon and the shadow (*samparkārdha*) by the square of the (Moon's) latitude (for the time of opposition of the Sun and Moon) and then take the square root (of that). That divided by the difference between the (true) daily motions (of the Sun and Moon) and multiplied by 60 gives, in *nāḍīs*, the (first approximation to the *sparśa-* or *mokṣa-*) *sthityardha.*

(Then) multiply those *nāḍīs* by the true daily motion (of the Moon) and always[1] divide by 60. The resulting minutes should then be severally subtracted from and added to the longitude of the Moon (calculated for the time of opposition) to get the longitudes of the Moon for the times of the first and last contacts.

From the Moon's longitude (for the first contact as also for the last contact) calculate the Moon's latitude; and from that successively determine the (corresponding *sthityardha* in terms of) *nāḍīs*, the corresponding minutes of arc (of the Moon's motion), and the longitude of the Moon (for the first contact as also for the last contact). Repeating this process again and again, find the nearest approximations to the (*sparśa-* and *mokṣa-*) *sthityardhas.*[2]

The term *samparkārdha* means "half the sum of (the diameters of) the eclipsed and eclipsing bodies". In the case of a lunar eclipse, it denotes the sum of the diameters of the Moon and the shadow. The term *sthityardha* means "half the duration (of the eclipse)" and denotes, in the case of a lunar eclipse, the time-interval between the first contact and opposition or between opposition and the last contact. The interval between the first contact and opposition is called the *sparśa-sthityardha* (or *spārśika sthityardha*) and that between opposition and the last contact is called the *mokṣa-sthityardha* (or *maukṣika sthityardha*).

The above three verses say how to find the *sparśa-* and *mokṣa- sthityardhas*. The method used is the method of successive approximations and may be explained as follows :

[1] i.e., in every approximation.

[2] Cf. *MBh*, v. 74-76(i).

See Fig. 7. AB is the ecliptic; S is the centre of the shadow for the time of opposition, the circle around S being the circumference of the shadow. CD is the Moon's orbit relative to the shadow centred at S, and M is the position of the Moon at the time of opposition. C_1D_1 is drawn through M parallel to AB.[1]

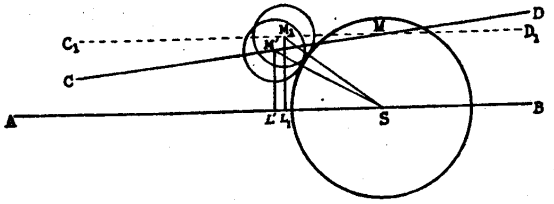

Fig. 7.

If the Moon's latitude M'L' for the time of the first contact were known, the *sparśa-sthityardha* could be obtained at once by considering the triangle M'L'S, right-angled at L'. But the Moon's latitude for the time of the first contact (viz. M'L') itself depends on the knowledge of the *sparśa-sthityardha*. Hence we use the method of successive approximations.

To begin with we neglect the variation of the Moon's latitude and take MS as the Moon's latitude throughout the eclipse. Thus we take M_1 to be the position of the Moon for the time of the first contact.

Let M_1L_1 be the perpendicular to the ecliptic. Then from the triangle M_1L_1S, right-angled at L_1, we have

$$L_1S=\sqrt{M_1S^2-M_1L_1^2}, \qquad (1)$$

where

M_1L_1=Moon's latitude,

and M_1S=half the sum of the diameters of the Moon and the shadow.

(1) gives L_1S, i.e., the distance along the ecliptic to be traversed by the Moon with respect to the shadow during the *sparśa-sthityardha*. Thus if m denote the dailymotion of the Moon with respect to the shadow, then

$$\textit{sparśa-sthityardha}=\frac{60\times L_1S}{m}\ \textit{nāḍīs}.$$

[1] Neither the ecliptic nor the Moon's orbit is a straight line but their arcs which we are considering are so small that they may be regarded as such without much error.

This is the first approximation to the *sparśa sthityardha.* Let us denote it by t_1.

Now we calculate the displacement of the Moon for the *sparśa-sthityardha* t_1, then diminish the Moon's longitude (calculated for the time of opposition) by that displacement, and then with the help of the resulting longitude calculate the Moon's latitude. Treating this as the Moon's latitude for the time of the first contact, we calculate, as before, the *sparśa-sthityardha* again. This is the second approximation to the *sparśa-sthityardha.* Let us denote it by t_2.

Repeating the above process, we calculate the successive approximations t_3, t_4, t_5.....to the *sparśa-sthityardha.* It can be easily seen that

$$t_1 < t_2 < t_3 < \ldots < t_n < \ldots < \frac{60 \times L'S}{m} .$$

Therefore, the sequence of the successive approximations to the *sparśa-sthityardha* is convergent. The convergence is also rapid, so that the third or fourth approximation generally gives a fairly good approximation to the *sparśa sthityardha.*

The method for finding the *mokṣa-sthityardha* is similar. The only difference is that in the second and the next successive approximations calculation is made of the Moon's latitude for the time of the last contact instead of that for the first contact.

A rule relating to the determination of the times of the first and the last contacts:

13. Diminish and increase the true time of opposition by the (*sparśa-* and *mokṣa-*) *sthityardhas,* obtained by the method of successive approximations, (respectively): then are obtained the times of the first and the last contacts. The time of the middle of the eclipse is the same as that (of opposition of the Sun and the Moon).[1]

This is how the exact times of the beginning and end of a lunar eclipse are determined. In practice, however, the exact beginning and end of an eclipse are not perceived with the unaided eye. A lunar eclipse is seen to begin after a portion of the Moon's disc is already obscured by the shadow.

[1] Cf. *MBh,* v. 35.

Śaṅkaranārāyaṇa tells us how to find the times when a lunar eclipse is actually seen to begin and end. He says:

"At the beginning, having diminished the sixteenth part of the Moon's diameter from half the sum of the diameters of the Moon and the shadow, (then) having squared it and subtracted from it the square of the Moon's latitude, one should obtain half the (apparent)duration of the lunar eclipse by the method of successive approximations. Or, one should multiply the sixteenth portion of that (semi-duration) in minutes by 60 and divide by the difference between the daily motions of the Sun and the Moon, and then reduce that to *vighaṭīs* etc. Having thus ascertained the corresponding time (in *vighaṭīs* etc.), the apparent instant of the first contact should be declared by adding that to the instant of the first contact. After that, in order to determine the instant of the last contact, the *mokṣa-sthityardha* obtained by the method of successive approximations should be added to the instant of opposition and the result taken, as before, as the instant of the last contact. There also the (apparent) time should be announced after diminishing it by one-sixteenth (of the time corresponding to the *mokṣa-sthityardha*). Then adding the two *sthityardhas* (*i.e.*, the *sparśa* - and *mokṣa- sthityardhas*), the sum should be declared, in *ghaṭīs* etc., to be the duration of the eclipse."[1]

In support of his statement, Śaṅkaranārāyaṇa[2] quotes the following verse of Ācārya Bhaṭṭa Govinda:

śaśidehāṣṭyaṁśonaṁ samparkadalaṁ yadā nateradhikam,

bhavati tadendugrahaṇaṁ na bhavatyalpe'rdhasamparke.[3]

i.e., When half the sum of the diameters of the Moon and the shadow diminished by the sixteenth portion of the Moon's diameter is greater than the Moon's latitude (for the time of opposition), then does a lunar eclipse occur (*i.e.*, is observed). When half the sum of the diameters of the Moon and the shadow (diminished by the sixteenth part of the Moon's diameter) is smaller, a lunar eclipse does not occur (*i.e.*, is not observed).

The statement that the time of the middle of the eclipse is the same as that of opposition of the Sun and Moon is only approximately true. An accurate expression for the difference between the two instants was first given by Gaṇeśa Daivajña (1520).

---

1 From Śaṅkaranārāyaṇa's comm. on the verse under consideration.

2 See his comm. on *LBh*, iv. 9.

3 शशिदेहाष्ट्यंशोनं सम्पर्कदलं यदा नतेरधिकम् ।
भवति तदेन्दुग्रहणं न भवत्यल्पेऽर्धसम्पर्के ॥

A rule for finding the *sparśa-* and *mokṣa- vimardārdhas*:

14. The square root of the difference between the squares of the Moon's latitude and half the difference between (the diameters of) the eclipsed and eclipsing bodies leads, as before, to the determination of the (nearest approximation in) *nāḍīs* of the (*sparśa-vimardārdha* as also of the *mokṣa-*) *vimardārdha*.[1]

The term *vimardārdha* means "half the duration of totality (of an eclipse)"[4] and denotes, in the case of a lunar eclipse, the interval between the times of immersion (of the Moon into the shadow) and opposition (of the Sun and Moon), or between the times of opposition (of the Sun and Moon) and emersion (of the Moon out of the shadow). The interval between the times of immersion and opposition is called the *sparśa-vimardārdha*; and the interval between the times of opposition and emersion is called the *mokṣa-vimardārdha*.

The method for finding the *sparśa-* and *mokṣa- vimardārdhas*, given above, is similar to that for finding the *sparśa-* and *mokṣa- sthityardhas*, stated in stanzas 10-12 above. The difference is that in place of the sum of the semi-diameters of the Moon and the shadow use is made in the present case of their difference.

The remainder of this chapter deals with the graphical representation of an eclipse. This requires the knowledge of *valana*, *i.e.*, the deflection of the ecliptic from the prime vertical on the horizon of the eclipsed body (*i.e.*, on the great circle having the eclipsed body at either of its poles). For the convenience of calculation, this *valana* is broken up into two components called the *akṣa-valana* and the *ayana-valana*. The former is the deflection of the equator from the prime vertical on the horizon of the eclipsed body, whereas the latter is the deflection of the ecliptic from the equator on the horizon of the eclipsed body. Thus if A, B, C be the points where the prime vertical, the equator, and the ecliptic intersect the horizon of the eclipsed body towards the east of the eclipsed body, then

the arc AB denotes the *akṣa-valana*,
the arc BC denotes the *ayana-valana*,
and the arc AC denotes the *valana*.

[1] Cf. *MBh*, v. 76(ii).

A rule relating to the determination of the magnitude and direction of the *akṣa-valana* :

15-16. Multiply the Rsine of the (local) latitude by the Rversed-sine of the *asus* between the times of (the beginning, middle, or end of) the eclipse and the middle of the night or day[1], and divide by the radius (*i.e.*, 3438′) : (the result is the Rsine of the *akṣa-valana*). The direction of the result (*i.e.*, *akṣa-valana*) is (determined) in the following manner :

(If the eclipsed body, at the time of the first or last contact, is) in the eastern half of the celestial sphere, the directions of the *akṣa-valana* for the eastern and western halves of the disc (of the eclipsed body) (*i.e.*, of the *sparśa-* and *mokṣa- valanas* in the case of the Moon and *vice versa* in the case of the Sun) are north and south (respectively); (if the eclipsed body is) in the western half of the celestial sphere, (they are to be taken) reversely.[2]

"The *asus* between the times of (the beginning, middle, or end of) the eclipse and the middle of the night or day" are the *asus* of the hour angle[3] of the eclipsed body for that time. Thus the rule given in the text is equavalent to the following formula :

$$Rsin\ (akṣa\text{-}valana) = \frac{\text{Rsin}\ \phi \times \text{Rvers}\ H}{3438'},$$

where H is the hour angle of the eclipsed body, and ϕ the latitude of the local place.

This formula, as pointed out by me in the *Mahā-Bhāskarīya* is inaccurate. For details see my notes on *MBh*, v. 42-44.

---

[1] Night when the eclipse is lunar and day when the eclipse is solar.

[2] Cf. *MBh*, v. 42-44.

[3] Measured east or west of the local meridian.

A rule relating to the determination of the magnitude and direction of the *ayana-valana* :

17. The Rsine of the declination calculated from the Rversed sine of the *koṭi* of the tropical (*sāyana*) longitude of the Sun or Moon[1] for that time (i.e., for the beginning, middle, or end of the eclipse) (is the Rsine of the *ayana-valana*). In the eastern half of the disc (of the Sun or Moon), the direction (of the *ayana-valana*) is the same as that of the *ayana*[2] (of the Sun or Moon). In the western half, the direction is contrary to that of the *ayana*.[3]

If λ be the tropical longitude of the eclipsed body, then its *koṭi* is $90°-\lambda$, $\lambda-90°$, $270°-\lambda$, or $\lambda-270°$, according as the eclipsed body is in the first, second, third, or fourth quadrant.

If K denote the *koṭi* of the tropical longitude of the eclipsed body, then, according to the above rule

$$\text{Rsin } (\textit{ayana-valana}) = \frac{\text{Rsin } \epsilon \times \text{Rversin} K}{\text{R}},$$

where ϵ is the obliquity of the ecliptic.

This formula is equivalent to that given by the author in the *Mahā-Bhāskarīya*, where K has been replaced by the *bhuja* of $\lambda+90°$.[4] For the *bhuja* of $\lambda+90°$ is equal to $90°-\lambda$, $\lambda-90°$, $270°-\lambda$, or $\lambda-270°$, according as the eclipsed body is in the first, second, third, or fourth quadrant.

As pointed out by me in the *Mahā-Bhāskarīya*,[5] the above formula is incorrect.

---

[1] The Sun is taken when the eclipse is solar, and the Moon is taken when the eclipse is lunar.

[2] *Ayana* means "the northerly or southerly course (of a planet)". The course (*ayana*) is north or south according as the planet lies in the half orbit beginning with the tropical sign Carpricorn or in that beginning with the tropical sign Cancer.

[3] Cf. *MBh*, v. 45.

[4] In my note to *MBh*, v. 45, Rversin $(\lambda+90°)$ stands as usual for Rversin {*bhuja* $(\lambda+90°)$}.

[5] v. 45, note.

A rule relating to the determination of the resultant *valana* corresponding to the circle having half the sum of the diameters of the eclipsed and eclipsing bodies for its radius:

18. Take the sum of their arcs (i.e., of the *akṣa-valana* and *ayana-valana*) when they are of like (directions) and the difference when they are of unlike directions. Multiply the Rsine of that (sum or difference) by the sum of the semi-diameters of the eclipsed and eclipsing bodies and divide by the radius: this result is the *valana*[1].

The *valana* obtained by this rule is the Rsine of the *valana* corresponding to a circle of radius equal to the sum of the semi-diameters of the eclipsed and eclipsing bodies.

A rule relating to the determination of the corrected *valana* (*sphuṭa-valana*):

19-20. If the *valana* (obtained above) is of the same direction (as the Moon's latitude) add it to the Moon's latitude; if it is of the contrary direction, subtract it (from the Moon's latitude). The (sum or difference thus obtained) is known as the corrected *valana* (*sphuṭa-valana*) in the case of solar and lunar eclipses[2].

In case that (corrected *valana*) is found to be greater than the sum of the semi-diameters of the eclipsed and eclipsing bodies, it should be subtracted from the entire sum of the semi-diameters of the eclipsed and eclipsing bodies and the remainder (thus obtained) should be taken as the (corrected) *valana*.

The corrected *valana* is supposed to give the distance of the centre of the eclipsing body from the east-west line drawn through the centre of the eclipsed body in the projected figure.

As pointed out by me in the *Mahā-Bhāskarīya*, the addition or subtraction of the *valana* and the Moon's latitude is not proper. Both the quantities

[1] Cf. *MBh*, v. 46-47(i).

[2] Cf. *MBh*, v. 47.

should be kept separately and laid off one after the other in the projected figure.

A rule relating to the *valana* for the middle of the eclipse:

21. The (resultant) *valana* for the middle of the eclipse obtained in the same way as for the first contact without any further addition or subtraction of the Moon's latitude is the corrected (*valana* for the middle of the eclipse). The direction of that (Moon's latitude) is to be taken reversely (in the projection of a lunar eclipse).[1]

What is meant is that the *valana* for the middle of the eclipse (which is calculated according to the rule stated in stanza 18) should not be combined with the Moon's latitude for that time (although such a rule is given in stanzas 19-20). The two quantities should be kept separately and laid off one after the other in the projected figure in the manner prescribed in stanzas 23-30 below.

The latter part of the stanza says that in drawing the figure of a lunar eclipse, the direction of the Moon's latitude is reversed. That is, when it is north, it is taken as south; and when it is south, it is taken as north. The reason is that in the case of a lunar eclipse, we find the position of the shadow with reference to the Moon; and when the Moon is north of the ecliptic (i.e., when the Moon's latitude is north), the shadow is to the south, and *vice versa*.

A rule for converting minutes of arc into *aṅgulas*:

22. The minutes of arc of the diameters of the Sun, Moon, and the shadow and those of the (Moon's) latitude and the (corrected) *valana* when divided by two are reduced to *aṅgulas*. (But when the Sun and Moon are) on the horizon, they (i.e., minutes of arc) are the same (as *aṅgulas*).[2]

A rule relating to the construction of the figure of an eclipse:

23-30. Draw a circle with a thread equal in length to half the *aṅgulas* of the diameter of the eclipsed body (as radius) and another (concentric circle) with a thread equal in length to half the sum of the diameters of the eclipsed and eclipsing bodies.

[1] Cf. *MBh*, v. 54, 77.

[2] Cf. *MBh*, v. 53(ii).

(Then) having drawn (through the common centre) the east-west line and with the help of a fish-figure the north-south line, lay off from the centre (of the circle) the corrected *valana* (for the first or last contact) according to its direction.

About that point draw a fish-figure (in the east-west direction). (Then) pass a thread through the middle of that fish-figure and produce it towards the east or west (as the case may be) to meet the outer circle and from there carry it to the centre.

The point where the junction of the circle of the eclipsed body and that (thread) is clearly seen (in the figure) is the place where the Moon is eclipsed or is separated (from the shadow).

When the *valana* and the Moon's latitude (for the middle of the eclipse) are alike in direction, the *valana* should be laid off towards the west (from the centre); otherwise, towards the east. In the case (of the eclipse) of the Sun, it should be done reversely. (Then) through the fish-figure drawn (along the north-south direction) about that point, pass a thread and extend it beyond the fish-figure (towards the north or south), according to (the direction of) the Moon's latitude to meet the outer circle, and from there carry the thread to the centre. Then from the centre along that thread lay off the Moon's latitude in the proper direction and put there a point.

(With that point as centre and) with the *aṅgulas* of the semi-diameter of the eclipsing body (as radius), draw a circle cutting the disc of the eclipsed body. The portion of the eclipsed body thus cut off lies submerged in the eclipsing body.[1]

The circle which is drawn through the points (i.e., the centres of the eclipsing body) corresponding to the beginning, middle, and end of the eclipse, with the help of two fish-figures, is the path of the eclipsing body.[2]

[1] Cf. *MBh*, v. 48-57.

[2] Cf. *MBh*, v. 61.

Construction of the phase of the eclipse for the given time:

31-32. Multiply the difference between the (true) daily motions (of the Sun and Moon) by the *sthityardha* minus the given time and divide that (product) by 60. Then adding the square of that to the square of the Moon's latitude (for the given time), take the square root (of that sum). (The square root thus obtained is the distance between the centres of the eclipsed and eclipsing bodies at the given time).

Lay that off from the centre so as to meet the path of (the centre of) the eclipsing body. With the meeting point as centre and half the diameter of the eclipsing body as radius, draw the eclipsed portion for the given time.[1]

[1] Cf. *MBh*, v. 62-65.

CHAPTER V

THE SOLAR ECLIPSE

Definition of the local divisor :

1. Multiply the radius by the Rsine of the colatitude and divide by the Rsine of the (Sun's) greatest declination : the result is called the local divisor.

The divisor defined here will be used in stanza 6 below. It is called local, because it depends on the latitude of the local place.

A rule relating to the determination of the tropical longitude of the meridian ecliptic point for the time of geocentric conjunction of the Sun and Moon :

2-4(i). Having calculated the *asus* (of the right ascension) of the traversed portion of the Sun's sign, by proportion with the right ascension of the Sun's sign,[1] and (then) having subtracted them from the *asus* between the times of geocentric conjunction of the Sun and Moon and midday, subtract the traversed portion of the Sun's sign from the Sun's longitude. From the remainder also subtract, in the reverse order, as many signs as have their right ascensions included (in the remaining *asus*) (as also) the degrees and minutes (of the fraction) of a sign, if any. The result (thus obtained) is known as the (tropical) longitude of the meridian ecliptic point in the forenoon.

(When the geocentric conjunction of the Sun and Moon occurs) in the afternoon, addition should be made of the untraversed portion of the Sun's sign, etc.[2]

As regards the determination of the *asus* between the times of geocentric conjunction of the Sun and Moon, and midday, the commentator Śaṅkaranārāyaṇa says : "On the desired day whatever be the time of geocentric conjunction of the Sun and Moon, convert that into *asus* and also reduce to *asus*

[1] "Right ascension of the Sun's sign" is the same as "the time of rising of the Sun's sign at Laṅkā."

[2] Cf. *MBh*, v. 8-11.

the true semi-duration of the day. If the geocentric conjunction of the Sun and Moon occurs in the forenoon, subtract the time of geocentric conjunction (in *asus*) from the true semi-duration of the day (in *asus*); and if the geocentric conjunction occurs in the afternoon, then from the time of geocentric conjunction (in *asus*) subtract the (true) semi-duration of the day (in *asus*) : in both the cases the remainder denotes the *asus* between the times of geocentric conjunction and midday."

Śaṅkaranārāyaṇa has given the full method for finding the tropical (*sāyana*) longitude of the meridian ecliptic point for the time of geocentric conjunction of the Sun and Moon when the geocentric conjunction occurs in the afternoon. He writes : "When the geocentric conjunction of the Sun and Moon occurs in the afternoon, then the semi-duration of the day is subtracted from the time of geocentric conjunction and thus is obtained the difference in *asus* between the times of geocentric conjunction and midday; the result is set down at some place; from these *asus* of the difference between the times of geocentric conjunction and midday are then subtracted the *asus* which are obtained by proportion from the untraversed portion in minutes of arc of the sign occupied by the Sun or Moon at the time of geocentric conjunction and the right ascension of the sign (i.e., the *asus* of the right ascension of the untraversed portion of the Sun's sign); the untraversed portion of the Sun's sign is then added to the Sun's tropical (*sāyana*) longitude for the time of geocentric conjunction; from the remaining *asus* are then subtracted in serial order the right ascensions of as many signs as possible and these signs are added to the Sun's longitude; finally, adding the degrees, minutes, etc., obtained on multiplying the remaining *asus* by 30 and dividing by the right ascension of the next sign is obtained the tropical (*sāyana*) longitude of the meridian ecliptic point."

Śaṅkaranārāyaṇa further says, "How is the longitude of meridian ecliptic point to be obtained when the traversed or untraversed part of the Sun's sign, while being subtractive, is less than the *asus* intervening between the time of geocentric conjunction of the Sun and Moon, falling near noon, and the time of midday ? There, the difference, in *asus*, between the times of geocentric conjunction and midday is itself multiplied by 30 and divided by the right ascension of the sign occupied by the Sun : the quotient subtracted from or added to the Sun's longitude according as the time of geocentric conjunction occurs in the forenoon or afternoon gives (the longitude of) the meridian ecliptic point."

It may be pointed out that in the above determination of the meridian ecliptic point, use is to be made of the Sun's tropical longitude, because the signs of the zodiac, whose right ascensions are made use of in the obove process, are tropical (*sāyana*). The resulting longitude of the meridian ecliptic point is also tropical.

A rule relating to the determination of the celestial latitude from the tropical longitude of the meridian ecliptic point obtained by the above rule :

4(ii). From that (tropical longitude of the meridian ecliptic point) diminished by the longitude of the Moon's ascending node calculate the celestial latitude, north or south, (as in the case of the Moon).

A rule relating to the determination of the *dṛkkṣepa* for the time of geocentric conjunction of the Sun and Moon :

5-7(i). Take the sum of the declination of the meridian ecliptic point and the celestial latitude (calculated from the tropical longitude of the meridian ecliptic point), and of the (local) latitude when they are of like directions and the difference when they are of unlike directions, the direction of the remainder (in the latter case) being that of the minuend. (The Rsine of the sum or difference is) the *madhyajyā*. By that multiply the Rsine of the *bhujā* of the tropical longitude of the rising point of the ecliptic and divide (the product) by the (local) divisor (defined in stanza 1). Square whatever is thus obtained and subtract that from the square of the *madhyajyā*. The remainder is the square of the Rsine of the *dṛkkṣepa*.

A rule relating to the determination of the *dṛggatijyā* for the time of geocentric conjunction :

7-(ii)-8(i). Having added that (square of the *dṛkkṣepajyā*) to the square of the Rsine of the instantaneous altitude (of the Sun), subtract that from the square of the radius : (the result is the square of the *dṛggaṭijyā*).

The *dṛkkṣepajyā* and *dṛggatijyā* obtained above, are neither precisely those for the Sun nor those for the Moon.[2] They would have been for the Sun, had the author not taken into account the celestial latitude calculated

[1] *MBh*, v. 14.

[2] The Sun's *dṛkkṣepajyā* is the Rsine of the zenith distance of that point of the ecliptic which is at the shortest distance from the zenith; and the Sun's *dṛggatijyā* is the distance of the zenith from the plane of the secondary to the ecliptic passing through the Sun. (*Contd. on the next page footnote*)

from the longitude of the meridian ecliptic point while finding the *madhyajyā*; whereas they would have been for the Moon, had the author, while calculating the value of the *dṛkkṣepajyā*, also taken into account the celestial latitude due to the rising point of the ecliptic (more correctly, the rising point of the Moon's orbit). See *MBh*, v. 13-23.

The intention of the author seems to find such values of the *dṛkṣkepajyā* and *dṛggatijyā* as may roughly correspond to both the Sun and the Moon. The artifice adopted for the purpose by him, however, is not mathematically correct. It would have been better if he had omitted the use of the celestial latitude calculated from the longitude of the meridian-ecliptic point. See Parameśvara's commentary on *LBh*, v. 11-12.

A rule relating to the determination of the *lambana-nāḍīs* for the time of apparent conjunction of the Sun and the Moon:

8-10. Having divided the square root thereof by 191, further divide the quotient by 4 and a half: the result in *nāḍīs* is the time known as *lambana* in the case of a solar eclipse. It is subtracted from the time of (geocentric) conjunction if the latter occurs in the forenoon. and is added to that if that occurs in the afternoon. To get the nearest approximation for the *lambana* (*i.e.*, the *lambana* for the time of apparent conjunction of the Sun and Moon), one should similarly perform the above operation again and again with the help of the time of (geocentric) conjunction.

The term *lambana* means the difference between the parallaxes in longitude of the Sun and Moon.

The above rule aims at finding the *lambana* in terms of time, for the time of apparent conjunction (in longitude) of the Sun and Moon. But as this *lambana* depends on the time of apparent conjunction of the Sun and Moon itself, which is unknown, so recourse is taken to the method of successive approximations prescribed in the text.

To begin with, the time of geocentric conjunction of the Sun and Moon is taken as the first approximation to the time of apparent conjunction, and

---

The Moon's *dṛkkṣepajyā* is the Rsine of the zenith distance of that point of the Moon's orbit which is at the shortest distance from the zenith; and the Moon's *dṛggatijyā* is the distance of the zenith from the plane of the secondary to the Moon's orbit passing through the Moon.

the corresponding *lambana* in *ghaṭīs* is obtained by the formula :—

$$lambana = \frac{dṛggatijyā}{191 \times 4\frac{1}{2}} \; ghaṭīs. \qquad (1)$$

The second approximation to the time of apparent conjunction is then obtained by the application of the formula :

time of apparent conjunction
= time of geocentric conjunction
± *lambana* in time for the time of apparent conjunction. (2)

The text prescribes the use of + or − sign in this formula according as the time of geocentric conjunction falls in the afternoon or in the forenoon. But this is incorrect; the correct procedure is to use + or − sign according as the Sun and Moon at the time of apparent conjunction lie to the west or to the east of the central ecliptic point.

The second approximation to the time of apparent conjunction of the Sun and Moon having been thus found, the above process is repeated again and again until the nearest approximation to the *lambana* for the time of apparent conjunction is arrived at.

The *rationale* of formula (1) is as follows :
We have (*vide MBh*, v. 24)

$$\text{Moon's parallax in longitude} = \frac{dṛggatijyā \times \text{Earth's semi-diameter in } yajanas}{\text{Moon's true distance in } yajanas} \text{ minutes of arc.}$$

But

$$\text{Moon's true distance in } yojanas = \frac{\text{Moon's mean daily motion in } yojanas \times 3438'}{\text{Moon's true daily motion in minutes of arc}},$$

so that

$$\frac{\text{Earth semi-diameter in } yojanas}{\text{Moon's true distance in } yojanas} = \frac{\text{Earth's semi-diameter in } yojanas}{\text{Moon's mean daily motion in } yojanas \times R} \times \times (\text{Moon's true daily motion in minutes of arc}).$$

$$= \frac{525}{7905{\cdot}8 \times 3438} (\text{Moon's true daily motion in minutes of arc}).$$

$$= \frac{\text{Moon's true daily motion in minutes of arc}}{15 \times 3438}$$

Therefore

Moon's parallax in longitude

$$=\frac{dṛggatijyā}{15\times 3438}\text{(Moon's true daily motion in minutes of arc), minutes of arc.}$$

Similarly,

Sun's parallax in longitude

$$=\frac{dṛggatijyā}{15\times 3438}\text{(Sun's true daily motion in minutes), minutes of arc.}$$

Therefore

lambana

$$=\frac{dṛggatijyā}{15\times 3438}\text{(Moon's true daily motion in minutes of arc}$$

$$-\text{Sun's true daily motion in minutes of arc).}$$

$$=\frac{dṛggatijyā}{3438}\times 4 \quad ghaṭīs$$

$$=\frac{dṛggatijyā}{191\times 4\frac{1}{2}}\ ghaṭīs.$$

The usual Hindu method for deriving this formula is to apply the following proportion:

"When the *dṛggatijyā* amounts to the radius (= 3438′), the *lambana* is equal to 4 *ghaṭīs*; what then would be the value of the *lambana* when the *dṛggatijyā* has its calculated value?"

The *ghaṭīs* of the *lambana* for the time of apparent conjunction having been thus determined, the time of apparent conjunction is obtained by using formula (2) above.

A rule relating to the determination of the *nati* for the time of apparent conjunction af the Sun and Moon:

11. Multiply the Rsine of the *dṛkkṣepa* obtained by the method of successive approximations[1] (i.e., multiply the Rsine of the *dṛkkṣepa* for the time of apparent conjunction) by the

[1] While finding the nearest approximation to the *lambana* for the time of apparent conjunction by the method of successive approximations, the Rsines of the *dṛkkṣepa* and the *dṛggati* were calculated at every stage. By the Rsine of the *dṛkkṣepa* obtained by the method of successive approximations is here meant the value of the Rsine of the *dṛkkṣepa* calculated at the last stage, which corresponds to the time of apparent conjunction.

difference between the daily motions (of the Sun and Moon) and divide by 51570 : the result is (the *nati*) in minutes of arc, etc.

The *nati* means the difference between the parallaxes in latitude of the Sun and Moon.

The *rationale* of the above rule is as follows :
We have (*vide MBh*, v. 28)

Moon's parallax in latitude

$$= \frac{dṛkkṣepa \times \text{Earth's semi-diameter in } yojanas}{\text{Moon's true distance in } yojanas} \text{ minutes.}$$

But, as before,

$$\frac{\text{Earth's semi-diameter in } yojanas}{\text{Moon's true distance in } yojanas}$$

$$= \frac{\text{Moon's true daily motion in minutes of arc}}{15 \times 3438}.$$

Therefore,

Moon's parallax in latitude

$$= \frac{dṛkkṣepa \times \text{Moon's true daily motion}}{15 \times 3438}.$$

Similarly,

Sun's parallax in latitude

$$= \frac{dṛkkṣepa \times \text{Sun's true daily motion}}{15 \times 3438}.$$

Hence

$$Nati = \frac{dṛkkṣepa}{15 \times 3438} \text{ [Moon's true daily motion—Sun's true daily motion].}$$

$$= \frac{dṛkkṣepa \times (\text{difference between true daily motions of the Sun and Moon})}{51570}$$

In the above *rationale* we have assumed that $\frac{525}{7905{\cdot}8} = \frac{1}{15}$ approx., and likewise taken $\frac{525}{7905{\cdot}8 \times 3438} = \frac{1}{51570}$. But this is incorrect, because $\frac{525}{7905{\cdot}8 \times 3438} = \frac{1}{51770}$ approx. Hence the commentator Parameśvara has suggested the reading *khasvarādryekabhutākhyaih* in place of *khasvareṣvekabhūtākhaih*.

A rule relating to the determination of the Moon's true latitude (i.e., the Moon's latitude corrected for parallax) for the time of apparent conjunction :

12. (The *nati*) and the Moon's latitude for that instant should be added if they are of like directions and subtracted if they are of unlike directions : thus is obtained the true latitude (of the Moon) in the case of a solar eclipse.[1]

"For that instant" means "for the time of apparent conjunction".

A rule relating to the determination of the *sparśa-* and *mokṣa-sthityardhas* :

13-14. From half the sum of the diameters of the Sun and the Moon and from the Moon's true latitude (for the time of apparent conjunction), calculate the *sthityardha*[2] as before.[3] (Subtracting that from and adding that to the time of apparent conjunction, find the gross values of the times of the first and last contacts). Then find out the *lambanas*[2] and the (Moon's) true latitudes for the times of the first and last contacts, applying the respective rules only once. Then add the difference of the *lambanas*[2] (for the times of the first contact and apparent conjunction at one place and for the times of apparent conjunction and the last contact at another place) to the *sthityardha*,[2] the results should be announced as the true values of the (*sparśa-* and *mokṣa-*)*sthityardhas*.[2] (Then subtracting the *sparśa-sthityardha*[2] from the time of apparent conjunction, find the time of the first contact; and adding the *mokṣa-sthityardha*[2] to the time of apparent conjunction, find the time of the last contact.)[4]

The *valanas* (for the times of the first contact, apparent conjunction, and the last contact) should be obtained as before.[5]

---

[1] Cf. *MBh*, v. 31.

[2] In *ghaṭīs*, etc.

[3] Cf. *MBh*, v. 34.

[4] Cf. *MBh*, v. 35-36.

[5] This last sentence is the translation of "*prāgvat valanakarma ca*", which occurs in the end of verse I3. We have shifted its translation to this place, because this is the most appropriate place for it.

The term *sthityardha* means "half the duration (of the eclipse)". The *sparśa-sthityardha*, in the case of a solar eclipse, is the time-interval between the first contact and apparent conjunction; and the *mokṣa-sthityardha* is the time-interval between apparent conjunction and the last contact.

The *sthityardha* is obtained as in the case of the lunar eclipse by the formula

$$sthityardha = \frac{\sqrt{\sigma^2 - \beta^2} \times 60}{d} \quad ghaṭīs,$$

where σ denotes half the sum of the diameters of the Sun and Moon, β the Moon's true latitude, and d the difference between the true daily motions of the Sun and Moon.

The *sparśa-* and *mokṣa- sthityardhas* obtained by the above rule give their approximate values only. To obtain the nearest approximations to the exact values one should apply the method of successive approximations. See *MBh*, v. 34-39.

Condition for the impossibility of a solar eclipse:

15. When the minutes of the (Moon's) true latitude (obtained above) are equal to the minutes of half the sum of the diameters of the Sun and the Moon, then the Moon does not hide the disc of the Sun, whose rays are the destroyers of darkness[1].

[1] Cf. *MBh*, v. 33.

CHAPTER VI

VISIBILITY, PHASES, AND RISING AND SETTING OF THE MOON

A rule relating to the visibility correction known as *akṣa-dṛk-karma* :

1-2. Multiply the Rsine of the Moon's latitude by the Rsine of the (local) latitude and divide (the product) by the Rsine of the colatitude. Whatever is thus obtained should be subtracted from the Moon's longitude in the case of rising of the Moon (i.e., in the eastern hemisphere) and added to that in the case of setting of the Moon (i. e., in the western hemisphere), provided that the Moon's latitude is north. When the Moon's latitude is south, the above correction is applied reversely in the cases of rising and setting (both).[1]

A rule relating to the visibility correction known as *ayana-dṛk-karma* :

3-4. Multiply the (Moon's) instantaneous latitude by the Rversedsine (of the Moon's longitude) as diminished by three signs and then by the Rsine of the (Sun's) greatest declination and divide that (product) by the square of the radius. The resulting minutes of arc should be subtracted from the longitude of the Moon when the latitude and *ayana* (of the Moon)[2] are of like directions. In the contrary case, they should always be added to the longitude of the Moon.[3]

The two corrections stated in the foregoing stanzas are known as *darśana-saṁskāra* or *dṛkkarma* (*"visibility corrections"*). The first correction, stated in stanzas 1-2, is known as *akṣa-dṛkkarma*.

---

[1] Cf. *MBh*, vi. 1-2(i).

[2] The Moon's *ayana* is north or south according as the Moon is in the half-orbit beginning with the tropical (*sāyana*) sign Capricorn or in that beginning with the tropical (*sāyana*) sign Cancer.

[3] Cf. *MBh*, vi. 2(ii)-3.

Suppose that a planet is rising on the eastern horizon or setting on the western horizon. Then the portion of the ecliptic lying between the hour circle of the planet and the horizon is defined as the *akṣa-valana* of the planet; and the portion of the ecliptic lying between the hour circle and the circle of longitude is defined as the *ayana-valava* of the planet.

The true longitude of a planet calculated in accordance with the rules stated in chapter II above denotes the longitude of that point of the ecliptic where the planet's circle of longitude meets it. The object of the visibility corrections is to obtain the longitude of that point of the ecliptic which rises or sets with the planet. This has been done in two steps by the successive application of the *akṣa-* and *ayana- dṛkkarmas*. The natural order, however, is to apply the *ayana-dṛkkarma* first and the *akṣa-dṛkkarma* next. Generally this natural order of correction has been followed by the Hindu astronomers.

The formulae for the *akṣa-* and *ayana- dṛkkarmas* for the Moon stated in the text are:

$$\textit{akṣa-dṛkkarma} = \frac{\text{R}\sin\phi \times \text{R}\sin(\text{Moon's latitude})}{\text{R}\cos\phi},$$

$$\textit{ayana-dṛkkarma}^1 = \frac{\text{Rversin}\,(M-90°) \times \text{R}\sin\epsilon \times \text{Moon's latitude}}{\text{R}^2},$$

where M is the Moon's (tropical) longitude, ϕ the latitude of the place, and ϵ the Sun's greatest declination.

For the *rationale* and discussion of these formulae, the reader is refered to my notes on *MBh*, vi. 1-3.

Minimum distance of the Moon from the Sun, in terms of degrees of time, at which she becomes visible:

5. When the Moon obtained by applying these (two visibility) corrections is found to be twelve degrees (of time) distant from the Sun, she shall be (just) visible in clear cloudless sky.[2]

---

[1] What the author really means is that:

$$\textit{ayana-dṛkkarma} = \frac{\text{Rversin}\,\{\text{bhujā}\,(M-90°)\} \times \text{R}\sin\epsilon \times \text{Moon's latitude}}{\text{R}^2}.$$

[2] Cf. *MBh*, vi. 4(ii)- 5(i). [While consulting my edition of the *MBh*, read "time of setting" in place of "oblique ascension" in line 21, p. 186, and "setting" in place of "oblique ascension" in line 31, p. 188. Similarly, the word "*asus*" occurring in lines 5 and 7, p. 192, should be changed into "*asus* of setting", and that occurring in line 9, p. 192, into "*asus* of rising". The last sentence of that paragraph should be deleted].

360 degrees of time are equivalent to 60 *ghaṭīs* or 21600 *asus*, so that one degree of time is equivalent to 1/6 of a *ghaṭī* or 60 *asus*. Thus 12 degrees of time are equivalent to 2 *ghaṭīs*.

On the fifteenth lunar day of the dark half of the month, the Moon comes near the Sun from behind and is lost in his splendour. After about two days she is beyond the limit of invisibility and is again seen in the sky after sunset, being in advance of the Sun.

In order to see whether the Moon will be visible on the first or second lunar day of the light half of the month, one should calculate the (tropical) longitude of the Sun for sunset on that day and also for the same time the (tropical) longitude of the Moon as corrected for the visibility corrections. If the portion of the ecliptic lying between the Sun and the Moon thus obtained sets at the local place in two *ghaṭīs* or more, the Moon will be visible after sunset on that day, otherwise not. Similarly, in order to see whether the Moon will be visible before sunrise on the fourteenth or fifteenth lunar day of the dark half of the month, one should calculate the (tropical) longitude of the Sun for sunrise on that day and also for the same time the (tropical) longitude of the Moon as corrected for the visibility corrections. If the part of the ecliptic lying between the Sun and Moon thus obtained rises at the local place in two *ghaṭīs* or more, the Moon will be visible before sunrise on that day, otherwise not.

A rule relating to the determination of the measures of the illuminated and unilluminated parts of the Moon :

6-7. (In the light half of the month) the Rversed-sine of the difference (between the longitudes of the Moon and the Sun) multiplied by the true diameter of the Moon and divided by 6876 gives the measure of the illuminated part (of the Moon). When the difference exceeds a quadrant, one should add the radius to the Rsine of the excess and from that (find) the measure of the illuminated part. In the dark half of the month, one should obtain in the same way, the unilluminated part (of the Moon) with the help of the Rversedsine (of the difference between the longitudes of the Moon and the Sun diminished by 6 signs) and from the Rsine (of the excess of that difference over a quadrant).[1]

[1]Cf . *MBh*, vi. 5(ii)-7.

That is, if the longitude of the Moon minus the longitude of the Sun be denoted by D, then

(i) *In the light half of the month,* the illuminated part of the Moon

$$= \frac{\text{Rversin } D \times \text{Moon's true diameter}}{6876},$$

if $D < 3$ signs; and

$$= \frac{[\text{R} + \text{Rsin } (D - 90°)] \times \text{Moon's true diameter}}{6876},$$

if $D > 3$ signs.

(ii) *In the dark half of the month,* the unilluminated part of the Moon

$$= \frac{\text{Rversin } (D - 180°) \times \text{Moon's true diameter}}{6876}$$

if $D > 6$ signs; and

$$= \frac{[\text{R} + \text{Rsin } (D - 270°)] \times \text{Moon's true diameter}}{6876},$$

if $D > 9$ signs.

"Moon's true diameter" means "Moon's angular diameter in minutes". See *supra,* ch. IV, stanza 5.

For the *rationale* of these formulae, see my notes on *MBh,* vi. 5 (ii)-7.

Verses 8-17 relate to the elevation of the horns of the Moon in the first quarter of the lunar month.

A rule regarding the determination of the Moon's *śaṅkvagra* at sunset:

8. From the *asus* intervening between the Sun and Moon (corrected for the visibility corrections) and from the Moon's earthsine and ascensional difference, determine the Rsine of the (Moon's) altitude; and from that find out the (Moon's) *śaṅkvagra,* which is always south (of the rising-setting line of the Moon).[1]

The *asus* intervening between the Sun and the Moon (corrected for the visibility corrections) are the *asus* to elapse before moonset. To obtain these *asus,* one should increase the above longitudes of the Sun and the Moon both by six signs and find the oblique ascension of the portion of the ecliptic lying between the two positions thus found.

The Moon's earthsine is the portion of the Moon's diurnal circle intercepted between the local and equatorial horizons. The Moon's ascensional differ-

[1] Cf. *MBh,* vi. 9.

ence is the corresponding time, i.e., the time that the Moon takes in moving from the equatorial horizon to the local horizon. The Moon's *śaṅkvagra* is the distance of the foot of the perpendicular dropped from the Moon on the plane of the horizon, from the rising-setting line of the Moon.

The methods of finding the Moon's earthsine, ascensional difference, altitude and *śaṅkvagra* are similar to those for the Sun.

A rule relating to the determination of the Moon's true declination and the Moon's *agrā* :

9-10. The Rsine of the difference or sum of the (Moon's) latitude and declination according as they are of unlike or like directions is (the Rsine of) the Moon's true declination.[1] From that (Rsine of the Moon's true declination) determine her day-radius, etc. Then multiply (the Rsine of) the Moon's (true) declination by the radius and divide by (the Rsine of) the colatitude : then is obtained (the Rsine of) the Moon's *agrā*.[2]

The true declination of the Moon means the declination of the centre of the Moon's disc.

The Rsine of the Moon's *agrā* is the distance between the east-west line and the Moon's rising-setting line.

A rule relating to the determination of the base (*bāhu*) :

11-12(i). If that (Rsine of the Moon's *agrā*) is of the same direction as the (Moon's) *śaṅkvagra*, take their sum ; otherwise, take their difference. Thereafter take the difference of (the Rsine of) the Sun's *agrā* and that (sum or difference) if their directions are the same, otherwise take their sum: thus is obtained the base (*bāhu*).[3]

Construction of the figure exhibiting the elevation of the lunar horns in the first quarter of the month at sunset :

12(ii)-17. Lay that (base) off from the Sun in its own direction. (Then) draw a perpendicular line passing through the head

[1] Cf. *MBh*, vi. 8.
[2] Cf. *MBh*, vi. 10-11(i).
[3] Cf. *MBh*, vi. 11(ii)-12.

and tail of the fish-figure constructed at the end (of the base). (This) perpendicular should be taken equal to the Rsine of the Moon's altitude and should be laid off towards the east. The hypotenuse-line should (then) be drawn by joining the ends of that (perpendicular) and the base.

The Moon is (then) constructed with the meeting point of the hypotenuse and the perpendicular as centre; and along the hypotenuse (from the point where it intersects the Moon's circle) is laid off the measure of illumination towards the interior of the Moon.

The hypotenuse (indicates) the east and west directions: the north and south directions should be determined by means of a fish-figure. (Thus are obtained the three points, viz.) the north point, the south point, and a third point obtained by laying off the measure of illumination.

(Then) with the help of two fish-figures constructed by the method known as *triśarkarāvidhāna* draw the circle passing through the (above) three points. Thus is shown, by the elevation of the lunar horns which are illumined by the light between two circles, the Moon which destroys the mound of darkness by her bundle of light.[1]

Exhibition of the lunar horns in the second quarter of the month:

18. (When the Moon is) in the eastern half of the celestial sphere, the true base should be found out with the help of the rising point of the ecliptic and the Moon's *agrā*, etc.; and the unmentioned element (i.e., the upright) should be laid off towards the west.[2]

The true base here corresponds to the base of stanza 11.

A rule for finding the duration of visibility of the Moon in the light half of the month:

19. The *nāḍīs* (of oblique ascension of the portion of the ecliptic) intervening between the Sun and the Moon[3] (at

[1] Cf. *MBh*, vi. 13-17.
[2] Cf. *MBh*, vi. 19.
[3] Corrected for the visibility corrections.

moonset), both increased by six signs, calculated by the method of successive approximations, give the duration of visibility of the Moon in the light half of the month.[1]

The process of successive approximations may be explained as follows: Compute the (tropical) longitudes of the visible Moon[2] and the Sun for sunset and increase both of them by six signs. Then find out the *asus* (A_1) due to oblique ascension of the part of the ecliptic lying between the two positions thus obtained. Then A_1 *asus* denote the first approximation to the duration of the Moon's visibility at night. Then calculate the displacements of the Moon and the Sun for A_1 *asus* and add them respectively to the longitudes of the visible Moon and the Sun for sunset, and increase the resulting longitudes by six signs; and then find out the *asus* (A_2) due to the oblique ascension of the part of the ecliptic lying between the two positions thus obtained. Then A_2 *asus* denote the second approximation to the duration of the Moon's visibility at night. Repeat the above process successively until the successive approximations to the duration of the Moon's visibility agree to *vighaṭīs*.

The time thus obtained is in civil reckoning. If, however, use of the Moon's displacement alone be made at every stage, the time obtained would be in sidereal reckoning.

According to the interpretation of the commentator Śaṅkaranārāyaṇa, the translation of the text would run as follows: "The *nāḍīs* (of oblique ascension of the portion of the ecliptic) lying between the Sun as increased by six signs and the Moon (at moonrise) calculated by the method of successive approximation give the time of moonrise (before sunset) in the light half of the month."

The process of successive approximations in this case would be as follows: Calculate the longitudes of the Sun and the visible Moon for sunset, and increase the former by six signs. Then find out the *asus* (B_1) due to oblique ascension of the part of the ecliptic lying between the two positions thus obtained. Then B_1 asus denote the first approximation to the time between moonrise and sunset. Then calculate the displacements of the Moon and the Sun for B_1 *asus*, and subtract them respectively from the longitudes of the visible Moon and the Sun for sunset, and, as before, increase the latter by six signs; and then find out the *asus* (B_2) due to the oblique ascension of the part of the ecliptic lying between the two positions thus obtained. Then B_2

---

[2] Cf *MBh*, vi. 27.

[3] i.e., the Moon corrected for visibility corrections.

asus denote the second approximation to the time between moonrise and sunset. Repeat the above process successively until the successive approximations to the time between moonrise and sunset agree. The time finally obtained, gives the time of moonrise before sunset. This being subtracted from the duration of the day gives the time of moonrise as measured since sunrise.

A rule relating to the time of rising of the Moon on the full moon day:

20-21. If (at sunset) on the full moon day the longitude of the Moon (corrected for the visibility corrections) agrees to minutes with the longitude of the Sun (increased by six signs), then the Moon rises simultaneously with sunset. If (the longitude of the Moon is) less (than the other), the Moon rises earlier; if (the longitude of the Moon is) greater (than the other), the Moon rises later.

(In the latter cases) multiply the minutes of the difference by the *asus* of the oblique ascension of the sign occupied by the Moon and divide by the number of minutes of are in a sign, and on the resulting time apply the method of successive approximations (and get the nearest approximation to the time to elapse at moonrise before sunset or elapsed at moonrise since sunset).[1]

When the longitude of the Moon is less than the longitude of the rising point of ecliptic (at sunset), the process of successive approximations will be similar to that explained under stanza 19 above while dealing with Śaṅkaranārāyaṇa's interpretation; when the longitude of the Moon is greater, the process of successive approximations will be similar to that explained below in stanzas 23-25.

A rule relating to the determination of the shadow of the gnomon due to the Moon:

22. From the *asus* (of the oblique ascension of the portion the ecliptic) lying between the rising point of the ecliptic and the Moon (corrected for the visibility corrections) or from those (taken in setting at the local place by the portion of the ecliptic) lying between the setting point of the ecliptic and the M

[1] Cf. *MBh*, v. 22.

(corrected for the visibility corrections) (according as the Moon is above the eastern or western horizon), and from the Moon's day radius, etc , determine (the Rsine of) the (Moon's) altitude and zenith distance and therefrom the shadow of the gnomon (due to the Moon)[1].

A rule for finding the time of moonrise in the dark half of the month:

23-25. Multiply the minutes of arcof the rising sign to be traversed by therising point of the ecliptic at sunset by the oblique ascension of thatsign and divide by the number of minutes of arc in a sign: thus are obtained the *asus* (of the oblique ascension of that part of the rising sign which is below the horizon). Adding thereto the *asus* (of the oblique ascension) of the succeeding portion of the ecliptic traversed by the Moon calculated for sunset up to the last minute of arc (of her longitude), find out the Moon's motion corresponding to that time by proportion, and add that to the longitude of the Moon. Then by repeating the above process again and again find the nearest approximation to the time between sunset and moonrise. After the lapse of that time during night, in the dark half of the month, is seen to rise the Moon who by her rays of light has destroyed the mound of darkness.[3]

The time obtained above is in sidereal reckoning. If the use of the Sun's displacement is also made at every stage, the resulting time would be in civil reckoning.

---

[1] See *supra,* Chapter iii, stanzas 7-10, 11.

[2] Corrected for the visibility corrections.

[3] Cf. *MBh,* vi. 28-31.

CHAPTER VII

VISIBILITY AND CONJUNCTION OF THE PLANETS

Minimum distances of the planets from the Sun at which they become visible:

1-2. If Venus corrected for the visibility corrections is 9 degrees (of time) distant from the Sun, it is visible. Jupiter, Mercury, Saturn, and Mars are visible in the clear sky when their distance (from the Sun) are nine degrees increased successively by twos (i.e., when they are respectively at the distances of 11, 13, 15 and 17 degrees of time from the Sun).[1] The degrees of time multiplied by 10 are known as *vināḍikās*.

Since 360 degrees of time are equivalent to 60×60 *vināḍikās*, therefore one degree of time is equivalent to 10 *vināḍikās*.

A rule relating to the determination of the degrees of time between the Sun and a planet:

3. (When the planet is to be seen) in the east, (its) visibility should be announced by calculating the time (of rising of the part of the ecliptic between the Sun and the planet[3]) by using the oblique ascension of that very sign (in which the Sun and the planet are situated); (when the planet is to be seen) in the west, (its) visibility should be announced by calculating the time (of setting of the part of the ecliptic between the Sun and the planet[3]) by using the oblique ascension of the seventh sign.[4]

A rule relating to the determination of the common longitude of two neighbouring planets when they are in conjunction in longitude:

4-5. Divide the difference between the longitudes of the two given planets by the sum or difference of their daily motions

[1] Cf. *MBh*, vi. 44. Also cf. *Ā*, iv. 4; *KK*, (Sengupta), vi. 6.

[2] Cf. *MBh*, vi. 46(i).

[3] Corrected for the visibility corrections.

[4] Cf. *MBh*, vi. 46(ii).

according as they are moving in unlike or like directions: then are obtained the days, etc. (elapsed since or to elapse before the time of conjunction of the two planets).[1] The longitude of those two neighbouring planets should then be made equal up to minutes of arc by subtracting from or adding to their longitudes their motions (corresponding to the above days, etc.) obtained by proportion with their true daily motions.[2]

To obtain the nearest approximation to the desired result, the above process should be repeated again and again.

A rule relating to the determination of the latitudes of the two planets which are in conjunction in longitude:

6-9(i). In the case of Mercury and Venus, subtract the longitude of the ascending node from that of the *śīghrocca*: (thus is obtained the longitude of the planet as diminished by the longitude of the ascending node).[3] The longitudes (in terms of degrees) of the ascending nodes of the planets beginning with Mars are respectively 4, 2, 8, 6, and 10 each multiplied by 10.[4]

The greatest latitudes, north or south, in minutes of arc, (of the planets beginning with Mars) are respectively 9, 12, 6, 12, and 12, each multiplied by 10.[5] (To obtain the Rsine of the latitude of a planet) multiply (the greatest latitude of the planet) by the Rsine of the longitude of the planet minus the longitude of the ascending node (of the planet) (and divide by the "divisor" defined below).[6]

The product of the *mandakarṇa* and the *śīghrakarṇa* divided by the radius is the distance between the Earth and the planet: this is defined as the "divisor".[7]

[1] Cf. *MBh*, vi. 49-50(i).
[2] Cf. *MBh*, vi. 51(i).
[3] Cf. *MBh*, vi. 53(ii). Also see *SiŚi*, II, vi. 23(i).
[4] Cf. *MBh*, vii. 10(i).
[5] Cf. *MBh*, vii. 9.
[6] Cf. *MBh*, vi. 52.
[7] Cf. *MBh*, vi. 48.

Thus are obtained the minutes of arc of the latitudes (of the two planets which are in conjunction in longitude).

Two things deserve mention here. One is that the revolution-numbers of the nodes of Mercury and Venus, stated in Hindu works on astronomy, as says Bhāskara II[1], are those increased by the revolution-nnmbers of their respective *śīghra-kendras*. The result is that when we subtract the longitude of the ascending node of Mercury or Venus from the longitude of its *śīghrocca*, we obtain the longitude of the planet (Mercury or Venus) as diminished by the longitude of its ascending node. The second is that in finding the celestial latitude of a planet we should use the heliocentric longitude of the planet and not the geocentric longitude. Brahmagupta (628 A. D.) and other Hindu astronomers have, therefore,prescribed the use of the true-mean longitude in the case of Mars, Jupiter and Saturn, and that of the longitude of the planet's *śīghrocca* as corrected for the planet's *mandaphala* in the case of Mercury and Venus.[2]

A rule relating to the determination of the distance between the two planets which are in conjunction in longitude :

9-10. From those latitudes obtain the distance between those two given planets by taking their difference if they are of like directions or by taking their sum if the are of unlike directions.[3]

The true distance between the two planets, in minutes of arc, being divided by 4 is converted into *aṅgulas*.[4]

Other things should be inferred from the colour and brightness of the rays of the (two) planets or else by the exercise of one's own intellect.[5]

---

[1] See *SiŚi*, II, viii. 23.

[2] See *BrSpSi*, ix. 9. Also see *SūSi*, ii. 56-57 ; *SiŚe*, xi. 15 ; and *SiŚi*, II, vi. 20-25(i).

[3] Cf. *MBh*, vi. 54.

[4] Cf. *MBh*, vi. 55.

[5] See *SūSi*, vii. 18(ii)-23(i).

CHAPTER VIII

CONJUNCTION OF A PLANET AND A STAR

Longitudes of the junction-stars[1] of the twenty-seven *nakṣatras* (zodiacal asterisms):

1-4. Eight, eighteen, ten, fourteen, twelve, eight, twenty-two, thirteen, nine, fourteen, thirteen, thirteen, nineteen, twelve, twelve, fifteen, ten, six, thirteen, thirteen, twelve, eighteen, eleven, twelve, twenty-one, seventeen, and fifteen— each of these numbers being increased by (the sum of) the preceding numbers, in the order in which they have been stated above, are to be taken as the degrees of the longitudes of the junction-stars of the (twenty-seven) *nakṣatras*. To the longitudes of (the junction-stars of) Pūrvāṣāḍha, Śravaṇa, Mūla, Maghā, Dhaniṣṭhā, Bharaṇī, and Uttarāṣāḍha (thus obtained), one should further add thirty minutes (of arc).[2]

The longitudes of the junction-stars stated above are, in some cases, slightly different from those given in the author's bigger work, the *Mahā-Bhāskarīya*. The differences are exhibited by the following table:

Differences between the longitudes of the junction-stars in the two works of Bhāskara I

Junction-star of	Longitude given in		Differen
	Mahā-Bhāskarīya	*Laghu-Bhāskarīya*	
1. Aśvin	8°	8°	
2. Bharaṇī	27°	26° 30′	—30′
3. Kṛttikā	1ˢ 6°	1ˢ 6°	

[1] The junction-stars (*yogatārā*) of the *nakṣatras* are the prominent stars of the *nakṣatras* which were used in the study of the conjunction of the planets, especially the Moon, with them.

[2] Cf. *MBh*, iii. 63-66(i).

Junction-star o	Longitude given in		Differenc
	Mahā-bhāskarīya	*Laghu-bhāskarīyo*	
4. Rohiṇī	1^s 19°	1^s 20°	+1°
5. Mṛgaśirā	2^s 2°	2^s 2°	
Ā rdrā	2^s 10°	2^s 10°	
7. Punarvasu	3^s 2°	3^s 2°	
8. Puṣya	3^s 15°	3^s 15°	
9. Āśleṣā	3^s 24°	3^s 24°	
10. Maghā	4^s 8° 30′	4^s 8° 30′	
11. Pūrvā Phālgunī	4^s 21°	4^s 21°	
12. Uttarā Phālgunī	5^s 4°	5^s 4°	
13. Hasta	5^s 23°	5^s 23°	
14. Citrā	6^s 5°	6^s 5°	
15. Svātī	6^s 17°	6^s 17°	
16. Viśākhā	7^s 2°	7^s 2°	
17. Anurādhā	7^s 12°	7^s 12°	
18. Jyeṣṭhā	7^s 18°	7^s 18°	
19. Mūla	8^s 1°	8^s 1° 30′	+30′
20. Pūrvāṣāḍha	8^s 14°	8^s 14° 30′	+30′
21. Uttarāṣāḍha	8^s 27°	8^s 26° 30′	—30′
22. Śravaṇa	9^s 15°	9^s 14° 30′	—30′
23. Dhaniṣṭhā	9^s 26°	9^s 25° 30′	—30′
24. Śatabhiṣak	10^s 7°	10^s 7°	
25. Pūrva Bhādrapada	10^s 28°	10^s 28°	
26. Uttara Bhādrapada	11^s 15°	11^s 15°	
27. Revatī	12^s	12^s	

Conjunction (in longitude) of a planet with a star:

5. All planets whose longitudes are equal to the longitude of the junction-star of a *nakṣatra* are seen in conjunction with that star.[1] (Of a planet and a star) whose longitudes are unequal, the time of conjunction is determined by proportion.

Latitudes of the junction-stars of the twenty-seven *nakṣatras*:

6-9. North, ten, twelve, five; south, five, ten, eleven; north, six, zero; south, seven, zero; north, twelve, thirteen; south, seven, two; north, thirty-seven; south, one and a half, three, four, eight and a half, seven, seven; north, thirty, thirty-six; south, eighteen minutes of arc; north, twenty-four, twenty-six, and zero—these have been stated by the learned to be the degrees (unless otherwise stated) of the latitudes of the junction stars of the *nakṣatras* beginning with Aśvinī in their serial order.[2]

The latitudes stated above are being exhibited below in the tabular form:

Latitudes of the Junction-stars of the Nakṣatras

Junction-star of	Celestial latitude	Junction-star of	Celestial latitude
1. Aśvinī	10°N	15. Svātī	37°N
2. Bharaṇī	12°N	16. Viśākhā	1°30′S
3. Kṛttikā	5°N	17. Anurādhā	3°S
4. Rohiṇī	5°S	18. Jyeṣṭhā	4°S
5. Mṛgaśirā	10°S	19. Mūla	8°30′S
6. Ārdrā	11°S	20. Pūrvāṣāḍha	7°S
7. Punarvasu	6°N	21. Uttarāṣāḍha	7°S
8. Puṣya	0	22. Śravaṇa	30°N
9. Āśleṣā	7°S	23. Dhaniṣṭhā	36°N
10. Maghā	0	24. Śatabhiṣak	18′S
11. Pūrvā-Phālgunī	12°N	25. Pūrva-Bhādrapada	24°N
12. Uttarā-Phālgunī	13°N	26. Uttara-Bhādrapada	26°N
13. Hasta	7°S	27. Revatī	0
14. Citrā	2°S		

[1] Cf. *MBh*, iii. 70(ii).

[2] Cf. *MBh*, iii. 66(ii)-70(i).

In the *Mahā-Bhāskarīya*, the latitudes of Mūla and Uttarāṣāḍha are stated to be 8°20′ S and 7°20′ S respectively.

Definition of absolute conjunction of the Moon with a star :

10. The Moon is in (absolute) conjunction with a junction-star when her longitude and celestial latitude both in magnitude and direction, are the same as the longitude and celestial latitude, in magnitude and direction, of the star.

Latitudes of the Moon when she occults some of the prominent stars of the zodiac:

11-16. When the Moon attains 160 minutes (of arc) of north latitude, she clearly covers the junction-star of the *nakṣatra* Kṛttikā (i.e., the Pleiades).[1]

Having attained her maximum northern latitude, the Moon covers with her disc the central star of the *nakṣatra* Maghā.[2]

With her latitude 60′ (south), the Moon clearly occults the cart of Rohiṇī (i.e., the V-shaped constellation of Hyades); and with latitude 256′ south, she covers the junction-star (of Rohiṇī) (i.e., Aldebaran).[3]

With her latitude 95 (minutes of arc) south, (the Moon covers the junction-star of) the *nakṣatra* Citrā (i e., Spica); with 150 (minutes of arc) south, (the junction-star of) the *nakṣatra* Anurādhā[4]; and with 200 (minutes of arc) (south), (the junction-star of) the *nakṣatra* Jyeṣṭhā (i.e., Antares).[5]

With latitude 87 (minutes of arc south), the Moon clearly occults (the brighter of) the two northern stars of the *nakṣatra* Viśākhā; with 24 (minutes of arc) south, (the junction-star of) the *nakṣatra* Śatabhiṣak (i.e., λ Aquarii).[6]

[1] Cf. *MBh*, iii. 74(i).

[2] Cf. *MBh*, iii. 74(ii).

[3] Cf. *MBh*, iii. 71(ii)-72(i).

[4] According to H. T. Colebrooke and E. Burgess, it is δ Scorpii. According to Bentley, it is β Scorpii.

[5] Cf. *MBh*, iii. 72(ii) -73(i).

[6] Cf. *MBh*, iii, 73.

The Moon, situated at her ascending node, occults (the junction-stars of) Puṣya and Revatī (i.e., ζ Piscium).[1]

The above occultations (*bheda*) of the stars by the planet (Moon) are based on the minutes of latitude determined from actual observation by means of the instrument (called) Yaṣṭi.[2]

An astronomical problem on indeterminate equations :

17. The sum, the difference, and the product increased by *one*, of the residues of the revolution of Saturn and Mars—each is a perfect square.[3] Taking the equations furnished by the above and applying the method of such quadratics obtain the (simplest) solution by the substitution of 2, 3, etc. successively (in the general solution). Then calculate the *ahargaṇa* and the revolutions performed by Saturn and Mars in that time together with the number of solar years elapsed.

Let x and y denote the residues of the revolution of Mars and Saturn respectively. Then we have to find out two numbers x and y such that each of the expressions $x+y$, $x-y$, and $xy+1$ may be a perfect square.

Let $x+y=4\alpha^2$, and $x-y=4\beta^2$, so that

$$x=2\alpha^2+2\beta^2$$

and $$y=2\alpha^2-2\beta^2.$$

Therefore $xy+1=(2\alpha^2-1)^2+4(\alpha^2-\beta^4)$.

Hence the condition that $xy+1$ be a perfect square is that

$$\alpha^2=\beta^4.$$

Consequently, we have

$$x=2(\beta^4+\beta^2)$$

and $$y=2(\beta^4-\beta^2),$$

---

[1] Cf. *MBh*, iii. 73(ii).

[2] Cf. *MBh*, iii. 75(i).

[3] According to Parameśvara's interpretation, the first half of this stanza means : "The sum, the difference, and the product of the residues of the revolution of Saturn and Mars, each increased by one, is a perfect square."

where $\beta=2, 3, 4, \ldots$, neglecting the case in which x or y is zero.[1]

Putting $\beta=2, 3, 4, \ldots$, we see that $x=40$ and $y=24$ is the least solution.

Assuming now that the residues of the revolution of Saturn and Mars are 24 and 40 respectively, we have to obtain the *ahargaṇa* and the revolutions performed by Saturn and Mars.

To obtain the *ahargana* and the revolutions performed in the case of Saturn, we have to solve the equation

$$\frac{3664\,1u-24}{394479375}=v, \qquad (1)$$

where u and v denote the *ahargaṇa* and the revolutions performed respectively.

Applying the rules given in the *Mahā-Bhāskarīya* (i. 41-45), the general solution of the above equation is found to be

$$u = 394479375t+346688814,$$
$$\text{and } v = 3664\,1t+32202,$$

where $t = 0, 1, 2, \ldots$. The least solution corresponds to $t = 0$.

To obtain the *ahargaṇa* and the revolutions performed in the case of Mars, the equation to be solved is

$$\frac{191402z-40}{131493125}=w, \qquad (2)$$

z and w denoting the *ahargaṇa* and the revolutions performed by Mars respectively.

The general solution of this equation is

$$z=131493125s+118076020,$$
$$w=191402s+171872,$$

---

[1] This solution was given by the Hindu Mathematician Nārāyaṇa (1356 A. D.). See *GK*, i. 47. The Hindu mathematician Brahmagupta (628 A.D.), who was a contemporary of Bhāskara I, had given the following solution :

$$x = A(\beta^2+\gamma^2),$$
$$y = A(\beta^2-\gamma^2),$$
$$\text{where } A=\frac{(\beta^2+\gamma^2)+(\beta^2-\gamma^2)}{[\frac{1}{2}\{(\beta^2+\gamma^2)-(\beta^2-\gamma^2)\}]^2},$$

which reduces to Nārāyaṇa's solution by taking $\gamma=1$.

The commentator Udayadivākara has given a unique method for solving the above multiple equations. His method has been discussed by me in a paper entitled "Ācārya Jayadeva, the mathematician". See *Gaṇita*, Vol. 5, No. 1, June 1954, pp. 18–19.

where $s=0, 1, 2, \ldots$. $s=0$ gives the least solution.[1]

Another astronomical problem on indeterminate equations:

18. The residue of the minute of Mars multiplied by the cube of two and increased by *one* yields a square-root (without remainder); that square number multiplied by seven and then further increased by *one* is again a perfect square. Having ascertained the residue from this (hypothesis) one who can find out the longitude of Mars and the *ahargaṇa* together with the number of solar years elapsed is (indeed) the foremost amongst the intelligent mathematicians on this earth girdled by the oceans.

Let x denote the residue of the minute of Mars, then we have to solve the equations

$$8x+1=y^2, \text{ say,} \quad (1)$$

$$7y^2+1=z^2, \text{ say,} \quad (2)$$

Eliminating y between (1) and (2), we get,

$$56x+8=z^2. \quad (3)$$

Evidently $x=1$, $z=8$ is a solution of this equation, so that we may take 1 as the residue of the minute for Mars.[2]

Let u be the *ahargaṇa* corresponding to this residue of Mars. Then

$$\frac{1653711328u-1}{5259725}=v, \quad (4)$$

where v denotes the revolutions performed by Mars is u days.

Solving (4) we get

u = 1863192 days,

v = 2712 revolutions, 0 sign, 25°, 31′,

which agrees with the solution given by the commentator Śaṅkaranārāyaṇa.

The commentator Śaṅkaranārāyaṇa has also given an alternative interpretation of the text. According to that interpretation the above stanza

[1] The results obtained above agree with those given by the commentator Śaṅkaranārāyaṇa. It may be noted that there is no *ahargaṇa* which may satisfy both equations (1) and (2) above. For, if we take $u=z$, then we get

$$394479375t-131493125s+228612794=0,$$

which is impossible.

[2] According to the commentator Udaya Divākara, one should first find the value of y by solving (2) and then substituting this value in (1) find x.

would run as follows :

"The residue of the minute of Mars multiplied by the cube of 2 yields a square root (without remainder); that square root being increased by one, then multiplied by 7 and then increased by one is again a perfect square. Having ascertained the residue from this (hypothesis), one who can find out the longitude of Mars and the *ahargana* together with the number of years elapsed is (indeed) the foremost amongst the intelligent mathematicians on this earth girdled by the oceans."

Let R be the residue of the minute of Mars. Then

$$7\ (\sqrt{8R+1})+1=s^2, \text{ say,}$$

so that

$$R=(1/8)\left\{\frac{s^2-8}{7}\right\}^2,$$

where R and s are integers.

Putting $s=0, 1, 2, \ldots$, we see that only $s=6$ and $s=8$ give integral values to R, the corresponding values being 2 and 8 respectively. Thus the residue of the minute of Mars is either 2 or 8.

Let us take $R=2$. Then to find out the required *ahargaṇa* we have to solve the equation

$$\frac{165371328x-2}{5259725}=y,$$

where x denotes the *ahargaṇa* and y the total number of minutes traversed by Mars.

The general solution of this equation is

$$x=5259725t+4386086,$$
$$y=165371328t+137903192,$$

where $t=0, 1, 2, \ldots$

If we take $R=8$, we shall get

$$\textit{ahargaṇa}=5259725s+3726384,$$

where $s=0, 1, 2, \ldots$

Śaṅkaranārāyaṇa gives the *ahargaṇa* as equal to 3726384 or 4386086. The former corresponds to $s=0$, and the latter to $t=0$.

Object, scope, and authorship of the book:

19. For acquiring a knowledge of the true motion of the planets by those who are afraid of reading voluminous works, the *Karma-nibandha* (*i.e.*, the *Mahā-Bhāskarīya*) has been briefly told by Bhāskara.

THEORY OF THE PULVERISER
As applied to Problems in Astronomy

by

BHAṬṬA GOVINDA

1. The following twenty-two stanzas dealing with the theory of the pulveriser as applied to problems in astronomy have been quoted by Śaṅkara Nārāyaṇa (in his commentary on *LBh*, viii, 18) from certain astronomical work (called Govinda-kṛti) of Ācārya Bhaṭṭa Govinda. These throw new light on the subject and will, it is hoped, be of interest to historians of mathematics.

2·1. Introduction to the subject :

यद्यप्युक्तं सकलं तथापि नैतत् प्रतीयते कर्म ।
अत इह कुट्टाकार गणितं सम्यक् प्रवक्ष्यामि ॥ १ ॥[1]

i.e., "Although the entire working of the pulveriser has been described (by previous writers), but it is not clearly understood. So here I explain the theory of the pulveriser more fully."

2·2. The two kinds of the pulveriser :

स पुनः कुट्टाकारो द्विविधस्तावन्निरग्रसाग्रतया ।
तत्र निरग्रो वाच्यः कुट्टाकारो मया पूर्वम् ॥ २ ॥[2]

i.e., "The pulveriser is of two varieties, residual and non-residual. Of these, the non-residual pulveriser will be explained by me first."

An indeterminate equation of the type

$$\frac{ax \pm c}{b} = y, \qquad (1)$$

$$\text{or } N = ax + R_1 = by + R_2 \qquad (2)$$

---

[1] *yadyapyuktaṁ sakalaṁ tathāpi naitat praitīyate karma |*
ata iha kuṭṭākāraṁ gaṇitaṁ samyak pravakṣyāmi ‖ 1 ‖

[2] *sa punaḥ kuṭṭākāro dvividhastāvanniragrasāgratayā |*
tatra niragro vācyaḥ kuṭṭākāro mayā pūrvam ‖ 2 ‖

is called a pulveriser (*kuṭṭākāra*). The pulveriser of the type (1) is called a non-residual pulveriser (*niragra-kuṭṭākāra*), and that of the type 2) is called a residual pulveriser (*sāgra kuṭṭākāra*).

The difference between the two types will become clearer by the following examples, of which the first relates to the non-residual pulveriser and the second to the residual pulveriser:

Ex. 1. "8 is multiplied by some number and the product is increased by 6 and then the sum is divided by 13. If the division be exact, what is the (unknown) multiplier and what the resulting quotient ?"

Ex. 2. "What is that number, O mathematician, which yields 5 as remainder when divided by 12, and 7 when divided by 31 ?"

The rules given in the following stanzas relate to the non-residual pulveriser, which is of the type (1). It may be mentioned that in equation (1), *a* is called the "dividend", *b* the "divisor", and *c* the "interpolator". When the interpolator is negative, it is technically called *gata* ; and when the interpolator is positive, it is called *gantavya.*

2·3. Preliminary operation:

गुणकारभागहारौ विभजेदन्योन्यभक्तशेषेण ।
तौ तत्र भाज्यहारौ दृढ़ाववाप्तौ विनिर्दिष्टौ ॥ ३ ॥
अन्योन्यशेषभक्तं गतगन्तव्यं यदा निरवशेषम् ।
तत्रेष्टाभ्यां कार्यं कुट्टनमन्यत्र दृढ़ाभ्याम् ॥ ४ ॥[1]

i.e., "Divide out the dividend (lit. multiplier) and the divisor by the (non-zero) remainder of their mutual division. The re-resulting dividend and divisor are then said to be prime to each other.

"When the *gata* (*i.e.*, negative interpolator) or *gantavya* (*i.e.*, positive interpolator) is found to be exactly divisible by the (non-zero) remainder of the mutual division, (it should be understood that the given interpolator corresponds to the true non-abraded values of the dividend and divisor, and so) one should proceed with the actual (non-abraded) values of the

[1] *guṇakārabhāgahārau vibhajedanyonyabhaktaśeṣeṇa ।*
tau tatra bhājyahārau dṛḍhāvavāptau vinirdiṣṭau ॥ 3 ॥
anyonyaśeṣabhaktaṁ gatagantavyaṁ yadā niravaśeṣam ।
tatreṣṭābhyāṁ kāryaṁ kuṭṭanamanyatra dṛḍhābhyām ॥ 4 ॥

dividend and divisor in solving a pulveriser. In the contrary case, (it should be understood that the given interpolator corresponds to the abraded values of the dividend and divisor, and so) one should proceed with their abraded values."

Let λ be the greatest common multiple of a and b; and let $a=\lambda A$ and $b=\lambda B$. If $c=\lambda C$, then according to the above rule, we have to solve the pulveriser

$$\frac{\lambda Ax \pm \lambda C}{\lambda B} = y,$$

or $$\frac{Ax \pm C}{B} = y,$$

If c is not divisible by λ, then we should solve the pulveriser

$$\frac{Ax \pm c}{B} = y.$$

In general, a pulveriser is said to be wrong when the interpolator is not divisible by the greatest common multiple of the dividend and the divisor. But in the present case, as will be seen from the following rule, the author while enunciating the above rule has in his mind a particular astronomical problem in which the dividend denotes the number of revolutions of a planet, the divisor the number of civil days, and the interpolator the residue of the revolution of the planet. And in such an astronomical problem, the residue of the revolution depends upon whether it has been obtained by using the actual values of the revolution-number and the civil days or by using their abraded values. Hence the justification of the above rule. It is presumed that the given problem is in no case incorrect.

2·4. The method of solving a pulveriser:

भाज्यं निधाय तदधो हारं च पुनः परस्परं छिन्द्यात् ।
लब्धमधोऽधः प्रथमावाप्तस्याधस्ततोऽप्यन्यत् ॥ ५ ॥
विभजेदेवं यावद् भाजकभाज्यावशून्यरूपौ स्तः ।
मतिकल्पना च विधिना समे पदे व्यत्ययाद्विषमे ॥ ६ ॥
भाज्याद्भाज्याहृतगतशेषोनाद् भाजकाभिहतदेहात् ।
गतसहिताद् भाज्याप्तं गतस्य हानौ मतिर्भवति ॥ ७ ॥
रूपोनहारगुणिताद्गन्तव्याप्तस्य भाज्यलब्धस्य ।
हारहृतस्य च शेषं योगे हारो मतिरशेषे ॥ ८ ॥
मतिहतभाज्याच्छोध्यं गतमगतं योजयेत्ततो विभजेत् ।
हारेण मतिं वल्ल्याऽधोऽधो निधायाप्तमप्यस्याम् ॥ ९ ॥

उपरिष्ठमुपान्त्यहृतं युतमन्त्येनैवमेव परतश्च ।
एव तावत् कुर्याद्यावद् द्वावेव तौ राशी ॥ १० ॥
उपरिस्थो हर्तव्यो हारेणाधःस्थितश्च भाज्येन ।
शेषं दिनादि चक्रादि च तत् स्याद्यच्च तेनाप्तम् ॥ ११ ॥[1]

i.e., "Set down the dividend and underneath that (dividend set down) the divisor, and then perform their mutual division. Write down the quotients (of mutual division) one below (the other: the second one under the first, the third one under the second, and so on. Carry on the mutual division till the (reduced) dividend and the (reduced) divisor are different from zero. If the number of quotients (thus obtained) is even, obtain the (number called) *mati* in accordance with the (following) rule; and if the number of quotients is odd, obtain the *mati* contrarily:[2]

"When the interpolator is negative, divide the interpolator by the (reduced) dividend (*bhājyāhṛta-gata*), then subtract the resulting remainder from the (reduced) dividend (*śeṣonād bhājyāt*), then multiply the remainder obtained by the (reduced) divisor (*bhajakābhihatadehāt*), then increase the resulting product by the interpolator (*gatasahitāt*), and then divide the resulting

[1] *bhājyaṁ nidhāya tadadho hāraṁ ca punaḥ parasparaṁ chindyāt ।*
labdhamadho'dhaḥ prathamāvāptasyādhastato'pyanyat ॥ 5 ॥
vibhajedevaṁ yāvad bhājakabhājyāvaśūnyarūpau staḥ ।
matikalpanā ca vidhinā same pade vyatyayādviṣame ॥ 6 ॥
bhājyādbhājyāhṛtagataśeṣonād bhājakābhihatadehāt ।
gatasahitād bhājyāptaṁ gatasya hānau matirbhavati ॥ 7 ॥
rūponahāraguṇitādgantavyāptasya bhājyalabdhasya ।
hārahṛtasya ca śeṣaṁ yoge hāro matiraśeṣe ॥ 8 ॥
matihatabhājyācchodhyaṁ gatamagataṁ yojayettato vibhajet ।
hāreṇa matiṁ vallyā'dho'dho nidhāyāptamapyasyām ॥ 9 ॥
upariṣṭhamupāntyahataṁ yutamantyenaivameva parataśca ।
evaṁ tāvat kuryādyāvad dvāveva tau rāśī ॥ 10 ॥
uparistho hartavyo hāreṇādhahsthitaśca bhājyena ।
śeṣaṁ dinādi cakrādi ca tat syādyacca tenāptam ॥ 11 ॥

[2] That is, assuming the dividend as the divisor, the divisor as the dividend, and the positive (or negative) interpolator as the negative (or positive) interpolator.

sum by the (reduced) dividend (*bhājyāptam*): the quotient (obtained) is the *mati*.

"When the interpolator is positive, diminish the (reduced) divisor by one (*rūponahāra*), by that multiply the interpolator (*rūponahāraguṇitāt gantavya*), divide that by the (reduced) dividend (*āptasya bhājyalabdhasya*), and then divide the (resulting) quotient by the (reduced) divisor (*hārahṛtasya*): the remainder (obtained) is the *mati*. In case the remainder is zero, the divisor itself is the *mati*.

"Multiply the (reduced) dividend by the *mati*; then subtract the *gata* (*i.e.*, negative interpolator) from or add the *gantavya* (*i.e.*, positive interpolator) to that (product); and then divide that (difference or sum) by the (reduced) divisor. Write down the *mati* under the chain (of quotients), and underneath that (*mati*) write down the quotient (obtained) also.

"By the penultimate number (of the chain of quotients) multiply the upper number and (to the product) add the last (*i.e.*, lowermost) number. (After doing this rub out the last number). Repeat this process again and again until there are left only two numbers in the chain.

"(Of these two numbers) divide the upper number by the divisor and the lower number by the dividend (if it is possible). The remainders (obtained) denote (respectively) the days, etc., and the revolutions, etc., which are the requisite quantities."

The above rule would be clear by the following example:

Ex. 3. The residue of the revolution (*bhagaṇa-śeṣa*) of Saturn is 24; find the days (*ahargaṇa*) and the revolutions performed by Saturn, given that the formula for the Sun's revolutions for A days is $36641A/394479375$.

Let x be the unknown days and y the unknown revolutions performed by Saturn in x days. Then we have to solve the pulveriser

$$\frac{36641x-24}{394479375}=y.$$

We see that the numbers 36641 and 394479375 are already prime to each other, so we proceed with these numbers.

Mutually dividing 36641 and 394479375 until the remainder is 1 (*i.e.*, nonzero), and writing down the successive quotients one below the other, we get

10766
15
2
7
22
2

The reduced dividend and reduced divisor are 1 and 3 respectively. Since the number of quotients obtained is even, and the interpolator is negative, we follow the rule for the negative interpolator and thus obtain 27 for the *mati*. Multiplying 1 by 27 and subtracting 24 from the product, we get 3 which divided by the reduced divisor 3 yields 1 as the quotient.

Writing down the *mati* and this quotient under the chain of quotients, we get

10766
15
2
7
22
2
27
1

Reducing the chain, we successively obtain

10766	10766	10766	10766	10766	3108044439	(multiplier)
15	15	15	15	288689	288689	(quotient)
2	2	2	18665	18665		
7	7	8714	8714			
22	1237	1237				
55	55					
27						

Dividing 3108044439 by 394479375, and 288689 by 36641, we get 346688814 and 32202 respectively as remainders.

Therefore $x=346688814$, $y=32202$.

These are the least integral values satisfying the equation.

2·5. An alternative method :

कृत्वा वा कर्तव्यः कुट्टाकारस्तु रूपयुतिवियुती ।
गुणकारो लब्धं च स्यातां तदुपर्यधःशेषौ ॥ १२ ॥

गुणकारगुणे शेषे लब्धगुणे हारभाज्यसंहृतयोः ।
शेषौ तत्र क्रमशो दिनचक्रादी भवेतां तौ ॥ १३ ॥[1]

i.e., "or (alternatively), solve the pulveriser by taking +1 (if the given interpolator is positive) or −1 (if the given interpolator is negative). The remainders (resulting in this way) from the upper and lower numbers (of the reduced chain) are the (corresponding) multiplier and quotient (respectively). Multiply the (given) interpolator severally by these multiplier and quotient and divide (the products thus obtained) by the divisor and the dividend (respectively). The remainders (thus obtained) are respectively the days, etc., and the revolutions, etc."

To get a solution of Ex. 3 by this method, we solve the pulveriser

$$\frac{36641\,x-1}{394479375}=y,$$

by the previous method, and get

$$x=113065211 \text{ (multiplier)},$$
$$y=10502 \text{ (quotient)}.$$

Now multiplying 113065211 by 24 and dividing the product by 394479375, we get 346688814 as remainder. These are the required days.

Again multiplying 10502 by 24 and dividing the product by 36641, we get 32202 as remainder. These are the required revolutions of Saturn.

This method is based on the consideration that if $x=A, y=B$ be a solution of $(ax\pm1)/b=y$, then $x=cA, y=cB$ will be a solution of $(ax\pm c)/b=y$.

The importance of this method lies in the fact that any astronomical problem like the one considered above may be solved by taking recourse to the table of solutions of the equations $(ax\pm1)/b=y$, for different values of a and b.

---

[1] *kṛtvā vā kartavyaḥ kuṭṭākārastu rūpayutiviyutī* ।
guṇakāro labdhaṁ ca syātāṁ taduparyadhaḥśeṣau ॥ 12 ॥
guṇakāraguṇe śeṣe labdhaguṇe hārabhājyasaṁhṛtayoḥ ।
śeṣau tatra kramaśo dinacakrādī bhavetāṁ tau ॥ 13 ॥

2 6. When the residue of the revolution is given in terms of signs, degrees, etc. :

राश्यादावुद्दिष्टे राश्यादेर्भागहारसंगुणितात् ।
राश्यादिमानलब्धं स्याच्छेषं मण्डलादीनाम् ॥ १४ ॥[1]

i.e., "When the residue (of the revolution) is given in terms of signs, etc., multiply those signs, etc., by the divisor and divide (the product) by the number of signs, etc., in a revolution : the quotient obtained is the residue of the revolution."

Suppose, for example, that the residue of the revolution of the Sun is given to be 4 signs, 28 degrees, and 20 minutes.

Since 4 signs, 28 degrees, and 20 minutes=8900′, therefore we multiply 8900 by 210389 (the divisor in this case)[2] and divide by 21600 (the number of minutes in a revolution). In this way we get 86688 as the quotient. This is the residue of the revolution.

To find the days and the revolutions performed by the Sun in this case, we will now have to solve the pulveriser

$$\frac{576\,x-86638}{210389}=y.$$

Following the above method we can also obtain the residue of the sign, if it be given in terms of degrees, minutes, etc.

2·7. When the residue of the sign, etc., is given, and not the residue of the revolution :

यच्छेषं युतहीनं तज्जातीयं सदा भवति भाज्यम् ।
इति राश्यादेः शेषे भाज्यो राश्यादिमानहृतः ॥ १५ ॥
राश्याद्याहृतभाज्यो हारेण यो भवत्यदृढ़रूपः ।
तत्रेष्टाभ्यां ताभ्यां शेषवशात्कर्म कर्तव्यम् ॥ १६ ॥[3]

---

[1] *rāśyādāvuddiṣṭe rāśyāderbhāgahārasaṁgunitāt ।*
rāśyādimānalabdhaṁ syāccheṣaṁ maṇḍalādīnām ॥ 14 ॥

[2] The formula for the Sun's revolutions corresponding to A days is $576A/210389$.

[3] *yaccheśaṁ yutahīnaṁ tajjātīyaṁ sadā bhavati bhōjyam ।*
iti rāśyādeḥ śeṣe bhōjyo rāśyādimānahataḥ ॥ 15 ॥
rāśyādyāhatabhōjyo hārena yo bhavatyadṛḍharūpaḥ ।
tatreṣṭābhyāṁ tābhyāṁ śeṣavaśātkarma kartavyam ॥ 16 ॥

प्रदृढं वा कर्तव्यं शुद्धया तेनापवर्त्य शेषं च ।
क्रियते मतिर्मतिमता तया पुनः कर्म कर्तव्यम् ॥ १७ ॥
दृढवासरे च गुणिते भाज्ये च तयोरदृढता स्यात् ।
ताभ्यां दृढीकृताभ्यामेव तदा कर्म कर्तव्यम् ॥ १८ ॥[1]

i.e., "The dividend should always be of the same denomination as the interpolator which has been added or subtracted. So when the interpolator is the residue of the sign, etc., then the dividend should be multiplied by the number of signs, etc., (in a revolution).

When the dividend as thus multiplied by the number of signs, etc., (in a revolution) is not prime to the divisor, then the process of the pulveriser should be performed with their actual (non-abraded) values, depending on the value of the residue (interpolator) (i.e., provided that the interpolator is completely divisible by the greatest common factor of the dividend as multiplied above and the divisor). In that case the multiplied dividend and the divisor as also the residue (interpolator) should be made prime to each other by dividing them by the (non-zero) remainder (of the mutual division of the first two). The intelligent person should (in this case also) find out the *mati* and proceed further with it (in the manner explained heretofore).

(In case the interpolator is not exactly divisible by the greatest common factor mentioned above, the following rule should be applied:) If the abraded number of days (viz. the abraded divisor) and the (abraded) dividend as multiplied (by the number of signs, etc., in a revolution) are found to be non-prime to each other, then the process of the pulveriser should be performed after having made them prime to each other.

---

[1] *pradṛḍhaā vā kartavyaṁ śuddhyā tenāpavartya śeṣaṁ ca ।*
kriyate matirmatimatā tayā punaḥ karma kartavyam ॥ 17 ॥
dṛḍhavāsare ca guṇite bhājye ca tayoradṛḍhatā syāt ।
tābhyāṁ dṛḍhīkṛtābhyāmeva tadā karma kartavyam ॥ 18 ॥

Verses 15 to 17 relate to the case when the given interpolator corresponds to the actual values of the dividend and divisor, and verse 18 to the case when the given interpolator corresponds to the abraded dividend and abraded divisor.

2·8. When the dividend is greater than the divisor:

हारादधिके भाज्ये हाराप्तं भाजितं पृथक्कृत्य ।
वल्ल्युपहारान्तं पूर्वोक्तं कर्म निष्पाद्य ॥ १९ ॥
तत्रोपरिराश्याहतपृथक्स्थसहितो भवेदधोराशिः ।
एष विशेषो गदितः परमपि तुल्यं पुरोक्तेन ॥ २० ॥[1]

i.e., "when the dividend is greater than the divisor, divide the dividend by the divisor and set down the quotient (obtained) in a separate place. Then (treating the remainder of the division as the new dividend) having carried out the aforesaid operations ending in the reduction of the chain (of quotients), increase the lower number (of the reduced chain) by the product of the upper number (of the reduced chain) and the quotient written in a separate place. This has been stated to be the difference (in this case); the other things are the same as stated before."

Ex. 4. Solve the pulveriser

$$\frac{23x-1}{7}=y.$$

Since the dividend 23 is greater than the divisor 7, we divide 23 by 7. Thus we get 3 as quotient and 2 as remainder. Treating 2 as the new dividend, we solve the pulveriser

$$\frac{2x-1}{7}=y.$$

The chain of quotient thus obtained is

3
1 (*mati*)
1

[1] *hārādadhike bhājye hārāptaṁ bhajitaṁ pṛthakkṛtya ।*
vallyupahārāntaṁ pūrvoktaṁ karma niṣpādya ॥ 19 ॥
tatroparirāśyāhatapṛthaksthasahito bhavedadhorāśiḥ ।
eṣa viśeṣo gaditaḥ paramapi tulyaṁ puroktena ॥ 20 ॥

The reduced chain is

4
1

Adding to the lower number 1 the product of the upper number 4 and the quotient obtained in the beginning, we get

4
13

Hence $x=4, y=13$.

2·9. When the residue of the sign, or degree, etc., is given. (*An alternative Process*):

केचिद्गृहादिशेषे (ज्ञाते) तन्मण्डलादिशेषस्य ।
तन्मानं चानयते भाज्यस्थाने तु परिकल्प्य ॥ २१ ॥
कृत्वा कुट्टाकारं मण्डलशेषेण तत्र लब्धेन ।
भगणानां च दिनानामानयने कुर्वते भूयः ॥ २२ ॥[1]

i.e., "When the residue of the sign, etc., is known, some (writers), assuming the number of signs, etc., in a revolution as the dividend and applying the process of the pulveriser, first find out the residue of the revolution, and then from the residue of the revolution obtain the revolutions (performed by the planet) and the days (*i.e.*, *ahargaṇa*) by applying the same process again."

The following example will illustrate this rule.

Ex. 5. The residue of the sign of the Sun is 154168; find the days (*ahargaṇa*) and the revolutions and signs of the Sun's longitude.

Here we first solve the pulveriser

$$\frac{12u-154168}{210389}=v,$$

where u denotes the residue of the revolution of the Sun, and v the signs of the Sun's longitude.

Thus we get

$$u=82977,$$
$$v=4.$$

[1] *kecidgṛhādiśeṣe (jñāte) tanmaṇḍalādiśeṣasya ।*
tanmānaṁ cānayate bhājyasthāne tu parikalpya ॥ 21 ॥
kṛtvā kuṭṭākāraṁ maṇḍalaśeṣeṇa tatra labdhena ।
bhagaṇānāṁ ca dinānāmānayane kurvate bhūyaḥ ॥ 22 ॥

Now we solve the pulveriser

$$\frac{576\,x-82977}{210339}=y,$$

where x denotes the days (*ahargaṇa*) and y the revolutions of the Sun's longitude.

We get $x=176564$, $y=5800$.

When the residue of the minute is given, then, according to the above rule, we first find the residue of the degree, then the residue of the sign, then the residue of the revolution, and then the days (*ahargaṇa*) and the revolutions.

PASSAGES FROM THE LAGHU-BHĀSKARĪYA QUOTED OR ADOPTED IN LATER WORKS

(*a*) PASSAGES QUOTED

Passages from the *Laghu-Bhāskarīya* occur as quotations in the following commentaries :

(1) Karavinda Svāmī's commentary on the *Āpastamba-śulba-sūtra.*

(2) The *Prayoga-racanā*, an anonymous commentary on the *Mahā-Bhāskarīya.*

(3) Sūryadeva's commentaries on the *Āryabhaṭīya* and the *Laghu-mānasa.*

(4) Yallaya's commentary on the *Āryabhaṭīya.*

(5) Nīlakaṇṭha's commentary on the *Āryabhaṭīya.*

(6) Raghunātha Raja's commentary on the *Āryabhaṭīya.*

(7) Commentary on the *Tantra-saṅgraha* of Nīlakaṇṭha.

(8) Govinda Somayāji's commentary, entitled *Daśādhyāyī*, on the *Brhajjātaka* of Varāhamihira.

(9) Viṣṇu Śarmā's commentary on the *Vidyā-mādhavīya.*

Below we refer briefly to these passages and to the places where they occur as quotations.

1. Passage quoted by Karavinda Svāmī.[1]

Passage quoted: *LBh*, iii. 1.

Quoted under: *Āpastamba-śulba-sūtra*, paṭala 1, khaṇḍa 1, sūtra 1.

2. Passages quoted in the *Prayoga-racanā.*

Passages quoted : *LBh*, i. 19-21, 22.

Quoted under: *MBh*, iv. 1-2.

---

[1] This passage shows that Karavinda Svāmī lived after Bhāskara I, *i.e.*, after A. D. 629. In this connection see B. Datta, *Science of the Śulba*, Calcutta (1932), pp. 16-17.

3. Passages quoted by Sūryadeva.

Sūryadeva has quoted a number of passages from the *Laghu-Bhāskarīya*, which are arranged below in the tabular form.

(i) Passages quoted in the commentary on the *Āryabhaṭīya*.

Passages quoted	Quoted under
LBh, i. 9(ii).	*Ā*, i. 2; iii. 6
LBh, i. 10-11(i)	*Ā*, i. 2.
LBh, i. 12(ii)-13(i)	*Ā*, i. 3.
LBh, i. 14(i)	*Ā*, i. 3.
LBh, i. 7(i)	*Ā*, iii. 6.
LBh, i. 14(ii)	*Ā*, i. 3; iii. 5.
LBh, i. 15-17	*Ā*, iii. 6.
LBh, iii. 26	*Ā*, iii. 22.
LBh, ii. 3(ii)	*Ā*, iii. 24.
LBh, ii. 6-7(i)	*Ā*, iii. 25.
LBh, iii. 5	*Ā*, iv. 25.
LBh, iv. 2-3	*Ā*, iv. 41.

(ii) Passages quoted in the commentary on the *Laghu-mānasa*.

Passages quoted	Quoted under
LBh, i. 49, 15-16	opening remarks
LBh, i. 10(i)	*LMā*, i. 8.
LBh, i. 12(ii), 10(i)	*LMā*, i. 9.
LBh, i. 11(i), 14(i)	*LMā*, i. 10.
LBh, i. 19-21	*LMā*, ii. introduction
LBh, ii. 8	*LMā*, ii. 4.
LBh, li. 8; i. 23; iii. 20	*LMā*, iii. 3.
LBh, iii. 5-6	*LMā*, iv. 2.
LBh, iii. 17-20	*LMā*, iv. 3.
LBh, ii. 29	*LMā*, iv. 4.
LBh, iv. 2-5	*LMā*, v. 3.
LBh, iv. 2, 3, 7	*LMā*, v. 4.
LBh, ii. 6-7(i)	*LMā*, v. 5.
LBh, iv. 8.	*LMā*, v. 6-7
LBh, iv. 11, 12, 14.	*LMā*, v. 13
LBh, vii. 2(i)	*LMā*, vi. 3

4. Passages quoted by Yallaya.

Passages quoted	Quoted in his comm. on
LBh, i. 15-17	*Ā*, iii. 6
LBh, ii. 6-7(i)	*Ā*, iii. 25
LBh, i. 14(ii)	*Ā*, iv. 4
LBh, i. 9(ii)	*Ā*, iv. 4

5. Passages quoted by Nīlakaṇṭha.

Passages quoted	Quoted in his comm. on
LBh, i. 1	*Ā*, iii. 11.
LBh, ii. 8, 15(ii), 9-10, 14-15(ii)	*Ā*, iii. 22-25
LBh, ii. 29	*Ā*, iii. 3
LBh, i. 14(ii).	*Ā*, ii. 32-33

6. Passages quoted by Raghunātha Rāja.

Passages quoted	Quoted in his comm. on
LBh, i. 9, 10, 11(i)	*Ā*, i. 2
LBh, i. 12, 13(i), 14(i)	*Ā*, i. 3
LBh, i. 14(ii)	*Ā*, i. 4

7. Passage quoted in the commentary on the *Tantra-saṅgraha*.

Passage quoted : *LBh*, iv. 9.
Quoted under : *TS*, iv. 20(ii)-21(i).

8. Passage quoted in the *Daśādhyāyī*.[1]

Passage quoted: *LBh*, iii. 5 ff.
Quoted under : *BJ*, i. 19

9. Passages quoted by Viṣṇu Śarmā.

Passages quoted :	*LBh*, v. 2-4(i)	*LBh*, viii. 1-5
Quoted under :	*ViMā*, i. 13	*ViMā*, xiv. 5

[1] This passage has been cited by S. Dvivedi in his *Gaṇaka-taraṅgiṇī* p. 14.

(*b*) Passages Adopted

The following verses occurring in the *Tantra-saṅgraha* ("A collection of *tantras*") of Nilakaṇṭha (1500 A. D.) are either verbatim reproduction or reproduction with verbal alterations of the verses found in the *Laghu-Bhāskarīya*:

1. (i) Version of the *Tantra-saṅgraha.*

देशान्तरघटीक्षुण्णा मध्याभुक्तिर्द्युचारिणाम् ।
षष्ट्या भक्तमृणं प्राच्यां रेखायाः पश्चिमे धनम् ॥[1]

(ii) Version of the *Laghu-Bhāskarīya.*

देशान्तरघटीक्षुण्णा मध्याभुक्तिर्द्युचारिणाम् ।
षष्ट्या भक्तमृणं प्राच्यां रेखायाः पश्चिमे धनम् ॥[1]

Both the versions of the same.

2. (i) Version of the *Tantra-saṅgraha.*

श्वस्तनेऽह्यतनाच्छुद्धे वक्रभोगोऽवशिष्यते ।
विपरीतविशेषोत्थः चारभोगस्तयोः स्फुटः ॥[2]

(ii) Version of the *Laghu-Bhāskarīya.*

श्वस्तनेऽह्यतनाच्छुद्धे वक्रभोगः प्रकीर्तितः ।
विपरीतविशेषोत्थश्चारभोगस्तयोः स्फुटः ॥[3]

3. (i) Version of the *Tantra-saṅgraha.*

उदक्स्थेऽर्के चरप्राणाः शोध्यास्स्वे याम्यगोलयोः ।
व्यस्तमस्ते तु संस्कार्या न मध्याह्नार्धरात्रयोः ॥[4]

---

[1] deśāntaraghaṭīkṣuṇṇā madhyā bhuktirdyucāriṇām ।
ṣaṣṭyā bhaktamṛṇaṁ prācyāṁ rekhāyāḥ paścime dhanam ॥
(*LBh*, i. 31).

[2] śvastane'dyatanācchuddhe vakrabhogo'vaśiṣyate ।
viparītaviśeṣotthaḥ cārabhogastayoḥ sphuṭaḥ ॥
(*TS*, ii. 68).

[3] śvastane'dyatanācchuddhe vakrabhogaḥ prakīrtitaḥ ।
viparītaviśeṣotthaścārabhogastayoḥ sphuṭaḥ ॥
(*LBh*, ii. 41).

[4] udakstheʼrke caraprāṇāḥ śodhyāśsvaṁ yāmyagolayoḥ ।
vyastamaste tu saṁskāryā na madyāhnārdharātrayoḥ ॥
(*TS*, ii. 29).

(ii) Version of the *Laghu-Bhāskarīya.*

उदग्गोलोदये शोध्या देया याम्ये विवस्वति।
व्यत्ययोऽस्तस्थिते कार्या न मध्याह्नार्धरात्रयोः ॥[1]

4. *TS*, ii. 53-56 and *LBh*, ii. 25-28 are also the same.

[1] udaggolodaye śodhyā deyā yāmye vivasvati।
vyatyayo'stasthite kāryā na madhyāhnārdharātrayoḥ ॥

(*LBh*, ii. 20)

GLOSSARY

of Terms used in the *Laghu - Bhāskariya*

Aṁśa (अंश) Degree (°).

Aṁśaka (अंशक) = *Aṁśa* (Degree)

Akṣa (अक्ष) Latitude. [The term *Akṣa* is an abbreviation of the complete term *Akṣonnati*, meaning "the inclination of the (earth's) axis (to the plane of the celestial horizon)", *i.e.*, the latitude of the place. *Akṣa* = axis, *unnati* = inclination.]

Akṣa-guṇa (अक्षगुण) The Rsine of latitude.

Akṣa-jīvā (अक्षजीवा) The Rsine of latitude.

Akṣa-jyā (अक्षज्या) The Rsine of latitude.

Akṣasya valanam (अक्षस्य वलनम्) See *Akṣavalana*.

Agata (अगत) Untraversed portion; portion to be traversed.

Agni (अग्नि) Three.

Agra (अग्र) (1) End. (2) *Agrā*.

Agrā (अग्रा) The arc of the celestial horizon lying between the east point and the point where the heavenly body concerned rises; or the Rsine thereof, which is equal to the distance between the east-west line and the rising-setting line of the heavenly body concerned.

Aṅga (अङ्ग) Six.

Aṅgula (अङ्गुल) Finger-breadth. A unit of linear measurement defined by the breadth of eight barley corns.

Adri (अद्रि) Seven.

Adhimāsa (अधिमास) Intercalary month.

The intercalary months denote the excess of the lunar (synodic) months over the solar months. Thus intercalary months in a *yuga* =lunar months in a *yuga* minus solar months in a *yuga*.

A true intercalary month is one in which the Sun does not pass from one sign into the next.

Anupāta (अनुपात) Proportion.

Anuloma (अनुलोम) Direct.

A planet is said to be *anuloma* when its motion is direct, *i.e.*, from west to east.

Anulomaga (अनुलोमग) A planet having direct motion, *i. e.*, moving from west to east.

Antarāla (अन्तराल) Interval.

Antya-jyā (अन्त्यज्या) The current Rsine-difference, *i.e.*, the Rsine-difference corresponding to the elementary arc occupied by a planet. In Hindu trigonometry a quadrant of a circle is divided into 24 equal parts, called elementary arcs.

Antya-maurvī (अन्त्यमौर्वी) Same as *Antya-jyā*.

Apakrama (अपक्रम) Declination.

Apakrama-dhanu (अपक्रमधनु) The arc of declination, or simply declination.

Apakrānti (अपक्रान्ति) Declination.

Apakrānti-cāpa (अपक्रान्तिचाप) The arc of declination.

Apakrānti-bhāga (अपक्रान्तिभाग) Declination.

Apama (अपम) Declination.

Apamo guṇaḥ (अपमो गुणः) The Rsine of declination.

Apara (अपर) (1) West. (2) *Aparāhṇa* or afternoon.

Aparā (अपरा) West.

Aparāhṇa (अपराह्ण) Afternoon.

Abdhi (अब्धि) Four.

Abhuktāṁśa (अभुक्तांश) Untraversed portion.

Abhyāsa (अभ्यास) Multiplication.

Amṛtatejas (अमृततेजस्) The Moon.

Ambara (अम्बर) Zero.

Ambhodhi (अम्भोधि) Four.

Ayana (अयन) The northward or southward course of a planet, particularly the Sun. The *ayana* of a planet is north or south according as the planet lies in the half-orbit beginning with the tropical sign Capricorn or in that beginning with the tropical sign Cancer.

Ayuta (अयुत) Ten thousand.

Arka (अर्क) (1) The Sun. (2) Twelve.

Arkaja (अर्कज) Saturn.

Arka-suta (अर्कसुत) Saturn.

Arkāgrā (अर्काग्रा) The Sun's *Agrā*. See *Agrā*.

Arkodaya (अर्कोदय) Sunrise.

Ardha-pañcama (अर्धपञ्चम) Four and a half ($4\frac{1}{2}$). Literally, five *minus* half.

Ardharātra (अर्धरात्र) Midnight.

Avanati (अवनति) Moon's true latitude as corrected for parallax.

Avamarātra (अवमरात्र) Omitted lunar days, or omitted *tithis*.

Aviśiṣta (अविशिष्ट) Obtained by applying the method of successive approximations.

Aviśeṣa-karma (अविशेषकर्म) Method of successive approximations.

Aviśeṣa-kalākarṇa (अविशेषकलाकर्ण) The distance (lit. hypotenuse) of a planet, in minutes, obtained by the method of successive approximations.

Aviśeṣaṇa (अविशेषण) Same as *Aviśeṣa-karma.*

Aśvi (अश्वि) Two.

Aśvin (अश्विन्) Two.

Aśvinī (अश्विनी) Name of the first *nakṣatra.*

Aṣṭi (अष्टि) Sixteen.

Asita (असित) (1) *Asita-pakṣa, i.e.*, the dark half of a lunar (synodic, month. (2) The measure of the unilluminated part of the Moon.

Asu (असु) A unit of time equal to four sidereal seconds.

Asta (अस्त) (1) The setting of a heavenly body. (2) *Asta-lagna, i.e.*, the setting point of the ecliptic.

Astamaya (अस्तमय) Setting.

Astodayāgra-rekhā (अस्तोदयाग्ररेखा) The rising-setting line.

Ahan (अहन्) Day.

Ahargaṇa (अहर्गण) The number of mean civil days elapsed since the beginning of Kali-yuga (or any other epoch).

Ahorātra (अहोरात्र) (1) A day and night, a nychthemeron. (2) The day-radius, *i.e.*, the radius of the diurnal circle.

Ahorātrā-dala (अहोरात्रदल) Same as *Ahorātrārdha-viṣkambha.*

Ahorātrāsu (अहोरात्रासु) The number of *asus* in a day and night, *i.e.*, 21600.

Ahorātrārdha (अहोरात्रार्ध) Same as *Ahorātrārdha-viṣkambha.*

Ahorātrārdha-viṣkambha (अहोरात्रार्ध-विष्कम्भ) Semi-diameter of the diurnal circle (of a heavenly body, particularly the Sun), *i.e.*, the day-radius.

Āditya (आदित्य) The Sun.

Āpya (आप्य) The *nakṣatra* Pūrvāṣāḍha, which is presided over by *Āpa.*

Āśā (आशा) Direction.

Indu (इन्दु) (1) The Moon. (2) One.

Indūcca (इन्दूच्च) The Moon's apogee, *i.e.*, the remotest point of the Moon's orbit.

Indvagra (इन्द्वग्र) Moon's *agrā.* See *Agrā.*

Iṣu (इषु) Five.

Iṣṭa (इष्ट) (1) Given, desired, or chosen at pleasure. (2) *Iṣṭa-graha, i.e.*, desired or given planet.

Iṣṭa-kāla (इष्ट-काल) Desired time or given time.

Iṣṭa-graha (इष्ट-ग्रह) Desired or given planet.

Iṣṭāsu (इष्टासु) Given *asus.*

Ucca (उच्च) *Ucca* (apex) is of two kinds: (1) *Mandocca* (apex of slowest motion), and (2) *Śīghrocca* (apex of fastest motion). The *mandocca* is that point of a planet's orbit which is at the remotest distance and where the motion of the planet is slowest. In the case of the

Sun or Moon, it is the apogee; and in the case of the other planets it is the apogee or aphelion, the geocentric longitude of the apogee being equal to the heliocentric longitude of the aphelion. The *śīghrocca* of a superior planet (Mars, Jupiter, or Saturn) is defined as the mean Sun; that of an inferior planet (Mercury or Venus) is an imaginary body which is supposed to more in such a way that its direction from the Earth is always approximately the same as that of the actual planet from the Sun.

Utkrama (उत्क्रम) (1) Reverse order. (2) *Utkramajyā*. See *Utkramajyā*.

Utkramajīvā (उत्क्रमजीवा) Same as *Utkramajyā*.

Utkramajyā (उत्क्रमज्या) Rversedsine. Rversin θ $\equiv$ Radius $\times$ $(1-\cos\theta)$.

Utkramajyā-phala (उत्क्रमज्याफल) Result (or correction) derived with the help of the *utkramajyā* of a certain arc.

Utkramabhavā jīvā (उत्क्रमभवा जीवा) Same as *Utkramajyā*.

Uttara (उत्तर) North.

Udak (उदक्) North.

Udaggola (उदग्गोल) Northern hemisphere.

Udaya (उदय) (1) The rising of a planet on the eastern horizon. (2) Heliacal rising of a planet. (3) *Udaya-lagna*, *i.e.*, the rising point of the ecliptic. (4) Addition, as in *Kṣayodayau* (subtraction and addition).

Upapluti (उपप्लुति) Eclipse.

Uṣṇadīdhiti (उष्णदीधिति) The Sun.

Ṛtu (ऋतु) Six.

Ekadikka (एकदिक्क) Same direction.

Aindrī (ऐन्द्री) The east, eastern direction (presided over by Indra).

Oja (ओज) Odd.

Kakubh (ककुभ्) Ten.

Karaṇa (करण) The name of one of the five principal elements of the Hindu Calendar.

Karkaṭa (कर्कट) The sign Cancer.

Karṇa (कर्ण) (1) The hypotenuse of a right-angled triangle. (2) The distance of a heavenly body.

Karṇabhukti (कर्णभुक्ति) True daily motion of a planet derived with the help of the planet's distance.

Karṇasūtra (कर्णसूत्र) The hypotenuse-line.

Kalā (कला) Minute of arc.

Kalpa (कल्प) Addition.

Kārmuka (कार्मुक) Arc.

Kālā (काल) Time.

Kālabhāga (कालभाग) The degrees of time.

One degree of time is equivalent to 60 *asus* or 10 *vināḍīs*.

Kāṣṭhā (काष्ठा) Direction.

Ku (कु) Earth.

Kuja (कुज) Mars.

Kṛta (कृत) Four.

Kṛti (कृति) Square.

Kṛttikā (कृत्तिका) The *nakṣatra* Kṛttikā.

Kendra (केन्द्र) (1) Anomaly. The *kendra* is of two kinds: (1) *manda-kendra*, and (2) *śīghra-kendra*. The *manda-kendra* of a planet is equal to "the longitude of the planet minus the longitude of the planet's *mandocca* (apogee)" and the *śīghra-kendra* of a planet is equal to "the longitude of the planet's *śīghrocca* minus the longitude of the planet." (2) Centre.

Kendra-bhukti (केन्द्रभुक्ति) The daily motion (or change) of a planet's anomaly (*kendra*); or anomalistic motion.

Koṭi (कोटि) (1) The upright of a right-angled triangle.

(2) The *Koṭi* corresponding to a planet's anomaly. If θ be the anomaly (or any arc or angle) then the corresponding *koṭi* is equal to 90°−θ, θ−90°, 270°−θ, or θ−270° according as $0 < \theta < 90°$, $90° < \theta < 180°$, $180° < \theta < 270°$, or $270° < \theta < 360°$.

Koṭiphala (कोटिफल) The result obtained by multiplying the Rsine of *koṭi* due to a planet's *kendra* by the tabulated epicycle and dividing the product by 80.

Koṭisādhana (कोटिसाधन) Same as *Koṭiphala*.

Koṭisūtra (कोटिसूत्र) The thread or line denoting the upright of a right-angled triangle; a perpendicular line.

Krama (क्रम) Serial order.

Kramajyā (क्रमज्या) Same as *Jyā*.

Kramabhavā jīvā (क्रमभवा जीवा) Same as *Kramajyā*.

Krānti (क्रान्ति) Declination.

Kriya (क्रिय) The sign Aries.

Kṣapābhartṛ (क्षपाभर्तृ) Moon.

Kṣaya (क्षय) Subtraction.

Kṣitija (क्षितिज) Mars.

Kṣitijyā (क्षितिज्या) Earthsine. The distance between the rising-setting line and the line joining the points of intersection of the diurnal circle and the six o'clock circle.

Kṣiti-suta (क्षितिसुत) Mars.

Kṣipti (क्षिप्ति) Celestial latitude.

Kṣipti-liptikāḥ (क्षिप्तिलिप्तिकाः) The minutes of celestial latitude.

Kṣepa (क्षेप) Used for *Vikṣepa* (celestial latitude).

Kha (ख) Zero.

Gaṇita (गणित) Calculation, computation.

Gaṇita-prakriyā (गणितप्रक्रिया) Calculation, computation.

Gata (गत) Traversed, elapsed, past, preceding.

Gati (गति) Motion. Generally used in the sense of "daily motion."

Gatyantara (गत्यन्तर) Motion-difference.

Gantavya (गन्तव्य) To be traversed, to come, succeeding.

Guṇa (गुण) (1) Multiple or multiplication. (2) Rsine.

Guru (गुरु) Jupiter.

Go (गो) The sign Taurus.

Gola (गोल) Hemisphere, northern or southern hemisphere.

Graha (ग्रह) (1) Planet. (2) Eclipse.

Grahaṇa (ग्रहण) Eclipse.

Grahamadhya (ग्रहमध्य) The middle of an eclipse.

Grahasadvartma (ग्रहसद्वर्त्म) True motion of a planet.

Grāsa (ग्रास) The eclipsed portion.

Grāhaka (ग्राहक) The eclipsing body, the eclipser.

Grāhakārdha (ग्राहकार्ध) Half the diameter of the eclipsing body.

Grāhya (ग्राह्य) The eclipsed body.

Grāhya-bimba (ग्राह्यबिम्ब) The disc of the eclipsed body.

Grāhya-maṇḍala (ग्राह्यमण्डल) The circle of the eclipsed body.

Ghaṭikā (घटिका) Same as *Ghaṭī*.

Ghaṭī (घटी) A unit of time equivalent to 24 minutes.

Ghāta (घात) Product, multiplication.

Cakra (चक्र) Circle, twelve signs, or 360°.

Cakraliptā (चक्रलिप्ता) The number of minutes of arc in a circle, *i.e.*, 21600.

Cakrārdha (चक्रार्ध) Half of a circle, *i.e.*, 180°.

Cakrāṁśaka (चक्रांशक) The number of degrees in a circle, *i.e.*, 360.

Candra (चन्द्र) The Moon.

Candrakarṇa (चन्द्रकर्ण) The distance of the Moon.

Candramas (चंद्रमस्) The Moon.

Cara (चर) Ascensional difference. It is defined by the arc of the celestial equator lying between the six o'clock circle and the hour circle of a heavenly body at rising.

Carajīvārdha (चरजीवार्ध) The Rsine of the ascensional difference.

Caraprāṇa (चरप्राण) Same as *Carāsu*.

Carāsu (चरासु) The *asus* of ascensional difference.

Cala-kendra (चलकेन्द्र) *Śīghra-kendra.* See *Kendra.*

Cala-kendra-phala (चलकेन्द्रफल) *Śīghra-phala.*

Calocca (चलोच्च) *Śīghrocca.*

Cāpa (चाप) Arc.

Cāpa-bhāga (चापभाग) An element of arc, or elementary arc (*i.e.*, one of the twenty-four equal divisions of a quadrant, the Rsine-differences for which have been tabulated by Āryabhaṭa I).

Cāpita (चापित) Converted into (or reduced to) the corresponding arc.

Cārabhoga (चारभोग) Direct motion.

Caitra (चैत्र) The name of the first month of the year.

Chāyā (छाया) (1) Shadow. (2) The Rsine of the zenith distance.

Chāyā-dairghya (छायादैर्घ्य) The length of the Earth's shadow, *i.e.*, the distance of the vertex of the Earth's shadow from the Earth's centre.

Chāyā-vidhāna (छायाविधान) The method of shadow.

Cheda (छेद) Divisor.

Jaladhi (जलधि) Four.

Jina (जिन) Twenty four.

Jīvā (जीवा) Same as *Jyā.*

Jīvābhukti (जीवाभुक्ति) True daily motion derived with the help of the table of Rsine-differences.

Jūka (जूक) The sign Libra.

Jyā (ज्या) (1) Rsine (=Radius × sine). (2) The Rsine-differences corresponding to the twenty four equal divisions of a quadrant.

Jyotis (ज्योतिस्) A heavenly body.

Tama (तम) The section of the cone of the Earth's shadow where the Moon crosses it, by a plane perpendicular to the axis of the shadow cone; briefly called "the shadow".

Tamomūrti (तमोमूर्ति) The Moon's ascending node.

Tamovyāsa (तमोव्यास) The diameter of the shadow. See *Tama.*

Tārakā (तारका) Star.

Tārā-samāgama (तारासमागम) Same as *Yogabhāga.*

Tigmatejas (तिग्मतेजस्) The Sun.

Tigmaraśmi (तिग्मरश्मि) The Sun.

Tigmāṁśu (तिग्मांशु) The Sun.

Tithi (तिथि) (1) Lunar day (called *tithi*). See notes on *LBh*, ii. 27. (2) Time of conjunction or opposition of the Sun and Moon (*parva-tithi*). (3) Time of beginning middle, or end of an eclipse. (4) Fifteen.

Tithi-varga (तिथिवर्ग) 15^2, or 225.

Tithyardhahāra (तिथ्यर्धहार) A divisor which is equal to half of that used in calculating the *tithi*, *i.e.*, 360.

Tiryak (तिर्यक्) Oblique.

Tulā (तुला) The sign Libra.

Tulyatva (तुल्यत्व) Equality.

Tulyadik (तुल्यदिक्) Like direction, or same direction.

Tulyādiktva (तुल्यदिक्त्व) Likeness or sameness of direction.

Trijyā (त्रिज्या) Radius or 3438′. Literally, the Rsine of three signs.

Trimaurvī (त्रिमौर्वी) Same as *Trijyā*.

Trirāśi (त्रिराशि) Three signs.

Triśarkarā-vidhāna (त्रिशर्करा-विधान) The method of constructing a circle through three given points has been called *triśarkarā-vidhāna* by Bhāskara I.

Trairāśika (त्रैराशिक) The rule of three.

Tvāṣṭra (त्वाष्ट्र) The *nakṣatra* Citrā which is presided over by त्वष्ट्रा.

Dakṣiṇa (दक्षिण) (1) South. (2) Southern hemisphere (*dakṣiṇa-gola*).

Dakṣiṇāśā (दक्षिणाशा) The southern direction.

Darśana-saṁskāra (दर्शन-संस्कार) usually called *Dṛkkarma* दृककर्म) Visibility corrections. There are two visibility corrections: (1) *Akṣa-dṛkkarma*, which is the measure of the arc of the ecliptic lying between the hour circle and the circle of position of the planet concerned, and (2) *Ayana-dṛkkarma*, which is measured by the arc of the ecliptic lying between the circle of celestial longitude and the hour circle of the planet concerned. These corrections having been applied to the true longitude of a planet, we obtain the longitude of that point of the ecliptic which rises on the local horizon simultaneously with the actual planet.

Dala (दल) Half.

Dasra (दस्र) Two. (*Dasra* is a synonym of *Aśvi*).

Dik (दिक्) (1) Direction. (2) Ten.

Dikka (दिक्क) Direction.

Dina (दिन) (1) Day. (2) Fifteen.

Dinagaṇa (दिनगण) Same as *Ahargaṇa*.

Dinapūrvāparārdha (दिनपूर्वापरार्ध) Forenoon and afternoon.

Dināntodayalāgna (दिनान्तोदयलग्न) The rising point of the ecliptic at sunset.

Dinārdha (दिनार्ध) Midday.

Diś (दिश्) (1) Direction. (2) Ten.

Diśā (दिशा) Direction.

Dṛkkṣepa (दृक्क्षेप) The *dṛkkṣepa* is the zenith distance of that point of a planet's orbit which is at the shortest distance from the zenith. This term is sometimes also used for the Rsine of that zenith distance.

Dṛkkṣepajyā (दृक्क्षेपज्या). The Rsine of the *dṛkkṣepa*. See *Dṛkkṣepa*.

Dṛśya-kāla (दृश्यकाल) Duration of visibility.

Deśāntara (देशान्तर) The longitude of a place. It is either the distance of the place from the prime meridian, or the difference between the local and standard times.

Deśāntara-ghaṭī (देशान्तरघटी) *Deśāntara*, in *ghaṭīs*, *i.e.*, the *ghaṭīs* of the difference between the local and standard times.

Dyugaṇa (द्युगण) Same as *Ahargaṇa*.

Dyucārin (द्युचारिन्) Planet.

Draṣṭā (द्रष्टा) Observer.

Dhana (धन) Addition.

Dhanu (धनु) Arc.

Dhanurbhāga (धनुर्भाग) The element of arc, or elementary arc (*i.e.*, one of the twenty-four equal divisions of a quadrant, the Rsine-differences of which have been tabulated by Āryabhaṭa I).

Dhanus (धनुस्) (1) Arc. (2) 225.

Dharā (धरा) The Earth.

Dhiṣṇya (धिष्ण्य, Star.

Dhṛti (धृति) Eighteen.

Naga (नग) Seven.

Nata (नत) Meridian zenith distance.

Natabhāga (नतभाग) Meridian zenith distance.

Nati (नति) (1) Meridian zenith distance, or the Rsine of that. (2) Difference between the parallaxes in latitude of the Sun and Moon.

Nabha (नभ) Zero.

Nabhaso madhya (नभसो मध्य) The meridian of the place. Literally, the middle of the sky

Naḍikā (नाडिका) Same as *Ghaṭī*.

Nāḍī (नाडी) Same as *Ghaṭī*.

Nirakṣajāḥ (*asavaḥ*) (निरक्षजाः असवः) *Asus* of right ascension, or the time in *asus* of rising at the equator.

Niśā (निशा) Night.

Niśākara (निशाकर) (1) The Moon. (2) One.

Niśākṛt (निशाकृत्) The Moon.

Niśānātha (निशानाथ) The Moon.

Pakṣa (पक्ष) Lunar fortnight, *i.e.*, the period from new moon to full moon, or from full moon to new moon. The period from new moon to full moon

is called the light fortnight (or the light half of a lunar month) and that from full moon to new moon is called the dark fortnight (or the dark half of a lunar month).

Pada (पद) (1) Quadrant. (2) Square root.

Padminībandhu (पद्मिनीबन्धु) The Sun.

Parama-krānti (परमक्रान्ति) Greatest declination of the Sun, *i.e.*, the obliquity of the ecliptic.

Parama-ksipti (परमक्षिप्ति) Greatest celestial latitude (of the Moon), *i.e.*, inclination of the Moon's orbit.

Paramāpakrama (परमापक्रम) Same as *Parama-krānti.*

Paramāpakramo guṇaḥ (परमापक्रमो गुणः) The Rsine of the Sun's greatest declination.

Paridhi (परिधि) (1) Circumference, periphery. (2) Epicycle.

Paryaya (पर्यय) Same as *Bhagaṇa.*

Parva (पर्व) (1) Time of conjunction or opposition of the Sun and the Moon. (2) Full moon or new moon *tithi.* (3) An eclipse of the Sun or Moon.

Parvata (पर्वत) Seven.

Parva-madhya (पर्वमध्य) The middle of an eclipse.

Parvanāḍī (पर्वनाडी) The *nāḍis* of the full moon or new moon *tithi* (also called *parva*) which are to elapse at sunrise on that day. Or, in other words, the time in *nāḍīs* which is to elapse at sunrise before the time of conjunction or opposition of the Sun and Moon.

Pala (पल) Latitude.

Palajyā (पलज्या) The Rsine of the latitude.

Paścārdha (पश्चार्ध) The western half.

Paścima (पश्चिम) West.

Pāta (पात) The ascending node of a planet's orbit (on the ecliptic).

Pāta-bhāga (पातभाग) The degrees of the longitude of the ascending node.

Pitrya (पित्र्य) The *nakṣatra* Maghā, which is presided over by *Pitṛ-s.*

Puṣkara (पुष्कर) Three.[1]

Puṣya (पुष्य) The *nakṣatra* Puṣya.

Pūrva (पूर्व) East.

Pūrvāparāyata (पूर्वापरायत) Directed east to west.

Pūrvāhṇa (पूर्वाह्ण) Forenoon.

Pauṣṇa (पौष्ण) The *nakṣatra* Revatī, which is presided over by Pūsā.

Paṅkti (पंक्ति) Ten.

Prakṛti (प्रकृति) Eight.

Prakṣepa (प्रक्षेप) Addition.

Prakriyā (प्रक्रिया) Process.

Pragrāsa (प्रग्रास) The beginning

[1] There are three *puṣkaras.* See *Vācaspatyam,* p. 3374, under *Tripuṣkara.*

of an eclipse, *i.e.*, the first contact.

Pratipad (प्रतिपद्) The first *tithi* of either half of a lunar month is called *Pratipad*.

Pratiloma (प्रतिलोम) Retrograde. A planet is said to be *pratiloma* when its motion is retrograde.

Prabhā (प्रभा) The shadow of a gnomon.

Prāk-kapāla (प्राक्कपाल) The eastern hemisphere.

Prāgvilagna (प्राग्विलग्न) The rising point of the ecliptic.

Prācī (प्राची) East.

Prāṇa (प्राण) Same as *Asu*.

Prāhṇa (प्राह्ण) Forenoon.

Phala (फल) Result or correction.

Bava (बव) The name of the first movable *Karaṇa*, the *Karaṇa* being one of the five important elements of the Hindu Calendar.

Bāhu (बाहु) (1) The base of a right-angled triangle. (2) The *bāhu* (or *bhujā*) corresponding to a planet's anomaly (or to any arc or angle). If θ be the anomaly of a planet (or any arc or angle whatever), then the corresponding *bāhu* is θ, $180°-\theta$, $\theta-180°$, or $360°-\theta$, according as $0<\theta<90°$, $90°<\theta<180°$, $180°<\theta<270°$, or $270°<\theta<360°$. (3) The Rsine of the *bāhu* (of a planet's anomaly).

Bāhuphala (बाहुफल) Correction due to the *mandocca* or *śīghrocca* of a planet. The formula for the *bāhuphala* is:

$$bāhuphala = \frac{bāhujyā \times \text{tabulated epicycle.}}{80}$$

Bindu (बिन्दु) Point.

Bimba (बिम्ब) Disc of a planet.

Budha (बुध) Mercury.

Bha (भ) Sign.

Bhagaṇa (भगण) The revolution-number of a planet, *i.e.*, the number of revolutions that a planet performs around the Earth in a certain period. The revolutions given by Bhāskara I correspond to a period of 43,20,000 years.

Bhava (भव) Eleven.

Bhāga (भाग) (1) Part, fraction. (2) Division. (3) Degree (°).

Bhāgahāra (भागहार) Divisor.

Bhājya (भाज्य) Dividend.

Bhānu (भानु) The Sun.

Bhārgava (भार्गव) Venus.

Bhāskara (भास्कर) (1) The Sun. (2) Twelve.

Bhāsvat (भास्वत्) The Sun.

Bhinna-dik (भिन्नदिक्) Unlike direction.

Bhinna-dikka (भिन्नदिक्क) Unlike direction.

Bhukta (भुक्त) Traversed, passed over.

Bhukti (भुक्ति) Motion, or daily motion.

Bhukti-yoga (भुक्तियोग) Sum of (daily) motions.

Bhukti-viśesa (भुक्तिविशेष) Motion-difference.

Bhuja (भुज) Same as *Bāhu.*

Bhujajyā (भुजज्या) The Rsine of *Bhuja* (*Bhujā* or *Bāhu*).

Bhujā (भुजा) Same as *Bāhu.*

Bhujā-phala (भुजाफल) Same as *Bāhu-phala.*

Bhujā-maurvī (भुजामौर्वी) Same as *Bhujajyā.*

Bhū (भू) Earth.

Bhū-cchāyā-dairghya (भूच्छायादैर्घ्य) Same as *Chāyā-dairghya.*

Bhūjyā (भूज्या) Same as *Kṣitijyā.*

Bhūta (भूत) Five.[1]

Bhū-tārāgraha-vivara (भूताराग्रहविवर) The distance between the Earth and a star-planet.

Bhūdina (भूदिन) Civil days.

Bhūmi (भूमि) Earth.

Bhūmi-vyāsa (भूमिव्यास) The diameter of the Earth.

Bhūmeḥ vṛttam (भूमेः वृत्तं) The circumference of the Earth.

Bheda (भेद) Occultation of a star.

Bhoga (भोग) Motion.

[1] There are five elements (*bhūta*), viz. earth, water, sacrificial fire, ether, and air.

Makara (मकर) Capricorn.

Maghā (मघा) The *nakṣatra* Maghā.

Maghā-madhyastha-tārakam (मघा-मध्यस्थतारकम्) The central star of the *nakṣatra* Maghā.

Maṇḍala (मण्डल) (1) Circle. (2) Revolution.

Maṇḍala-madhya (मण्डलमध्य) The centre of a circle.

Maṇḍalārdha (मण्डलार्ध). Half of a revolution, *i.e.*, six signs, or 180°.

Matsya (मत्स्य) Fish-figure.

Madhya-cchāyā (मध्यच्छाया) The midday shadow (of the gnomon).

Madhya-jīvā (मध्यजीवा) The Rsine of the zenith distance of the meridian-ecliptic point.

Madhyajyā (मध्यज्या) Same as *Madhya-jīvā.*

Madhya-bhukti (मध्यभुक्ति) Mean (daily) motion.

Madhyama (मध्यम) (1) Mean. (2) Mean planet (*madhyama-graha*).

Madhyamā bhuktiḥ (मध्यमा भुक्तिः) Mean (daily) motion.

Madhya-lagna (मध्यलग्न) Meridian-ecliptic point.

Madhyā bhuktiḥ (मध्या भुक्तिः) Mean (daily) motion.

Madhyāhna (मध्याह्न) Midday.

Madhyāhna-cchāyā (मध्याह्नच्छाया) The midday shadow (of the gnomon).

Manu (मनु) Fourteen.

Manda (मन्द) (1) *Mandocca.* (2) *Manda-paridhi* (*manda* epicycle).

Mandocca (मन्दोच्च) The apogee of a planet. See *Ucca.*

Mandocca-karṇa (मन्दोच्चकर्ण) *Manda-karṇa.*

Mandocca-phala (मन्दोच्चफल) Correction due to a planet's *mandocca.*

Mandāṁśa (मन्दांश) The longitudes of the apogees of the planets in terms of degrees.

Māsa (मास) A (lunar) month.

Māheya (माहेय) Mars.

Muni (मुनि) Seven.

Mūla (मूल) (1) Square root. (2) The *nakṣatra* Mūla.

Mṛga (मृग) The sign Capricorn.

Medinī (मेदिनी) Earth.

Meṣa (मेष) The sign Aries.

Maitra (मैत्र) The *nakṣatra* Anurādhā, which is presided over by Mitra.

Mokṣa (मोक्ष) The separation of the eclipsed body after an eclipse, the last contact, or the end of an eclipse.

Maurvī (मौर्वी) Rsine.

Yama (यम) (1) Saturn. (2) Two.

Yamala (यमल) Two.

Yāta (यात) Elapsed.

Yāmya (याम्य) (1) The south direction which is presided over by Yama. (2) The southern hemisphere (*yāmya-gola*). (3) The *nakṣatra* Bharaṇī, which is presided over by Yama.

Yāmyottara (याम्योत्तर) The local meridian.

Yugādhika (युगाधिक) Intercalary months in a *yuga.*

Yugma (युग्म) Even.

Yuti (युति) Union, junction.

Yoga (योग) (1) Conjunction in longitude of two heavenly bodies. (2) Addition.

Yoga-tārā (योगतारा) Junction-stars. These are those prominent stars of the twenty-seven *nakṣatras* which were used by the Hindu astronomers for the study of the conjunction of the planets, especially the Moon, with them.

Yoga-bhāga (योगभाग) The degrees of longitudes of the junction-stars.

Yojana (योजन) The *yojana* is a unit of distance. The length of a *yojana* has differed at different places and at different times. The *yojana* of Āryabhaṭa I and Bhāskara I is roughly equivalent to $7\frac{1}{2}$ miles.

Yojana-karṇa (योजनकर्ण) The distance of a planet in terms of *yojanas*.

Yojana-vyāsa (योजनव्यास) The diameter in terms of *yojanas*.

Randhra (रन्ध्र) Nine.

Ravi (रवि) (1) The Sun. (2) Twelve.

Rasa (रस) Six.

Rājaputra (राजपुत्र) Mercury, Literally, the son of the king (Moon).

Rāma (राम) Three.[1]

Rāśi (राशि) Sign.

Rāśi-kalā (राशिकला) The number of minutes in a sign, *i.e.*, 1800.

Rāśi-traya (राशित्रय) Three signs.

Rāśi-śeṣa (राशिशेष) The residue of the sign.

Rudra (रुद्र) Eleven.

Rūpa (रूप) One.

Rekhā (रेखा) (1) Line. (2) Prime-meridian.

Lagna (लग्न) The rising point of the ecliptic.

Laṅkā (लंका) A hypothetical place on the equator where the meridian of Ujjain intersects it.

Laṅkodaya (लंकोदय) Times of rising (of the signs) at Laṅkā, or right ascensions (of the signs).

Lambaka (लम्बक) The Rsine of the colatitude.

Lambaka-guṇa (लम्बकगुण) Same as *Lambaka*.

Lambana (लम्बन) Parallax in longitude; or, in particular, the difference between the parallaxes in longitude of the Sun and Moon.

Liptā (लिप्ता) Minute of arc.

Liptā-vyāsa (लिप्ताव्यास) Diameter (of a planet) in minutes.

Liptā-śeṣa (लिप्ताशेष) The residue of the minute.

Liptikā (लिप्तिका) Same as *Liptā*.

Vakratva (वक्रत्व) Curvature.

Vakrabhoga (वक्रभोग) Retrograde motion.

Vakrārambha (वक्रारम्भ) Commencement of retrograde motion.

Vatsara (वत्सर) Year.

Varga (वर्ग) Square.

Varga-vidhi (वर्गविधि) Method of solving a quadratic equation.

Varga-rāśi (वर्गराशि) A square quantity.

Vārtamāna (वर्तमान) Present, current.

Vartamāna-guṇa (वर्तमानगुण) The present (or current) Rsine-difference of the elementary arc occupied by a planet.

[1] There were three persons called Rāma, Parasurāma, Balarāma and Rāma.

Vartamāna-graha (वर्तमान-ग्रह) The longitude of a planet (at sunrise) on the current day.

Vartamānodaya (वर्तमानोदय) Time of rising of the sign lying, at the present moment, on the eastern horizon.

Vartma (वर्त्म) Path, locus.

Vartmavṛtta (वर्त्मवृत्त) The circle denoting a path (or locus).

Varṣa (वर्ष) Year.

Varṣa-pūga (वर्षपूग) A collection of years, or simply years.

Valana (वलन) (lit. deflection).

Valana relates to an eclipsed body. It is the angle subtended at the body by the arc joining the north point of the celestial horizon and the north pole of the ecliptic (*i.e.*, the angle between the circle of position and the circle of celestial longitude of the eclipsed body). *Valana* is generally divided into two components, (1) *Akṣa-valana*, and (2) *Ayana-valana*. The *Akṣa-valana* is the angle subtended at the body by the arc joining the north point of the celestial horizon and the north pole of the celestial equator (*i.e.*, the angle betwen the circle of position and the hour circle of the eclipsed body). The *Ayana-valana* is the angle subtended at the body by the arc joining the north poles of the equator and the ecliptic (*i.e.*, the angle between the hour circle and the circle of celestial longitude of the eclipsed body).

The *Valana* is also defined as follows: The great circle of which the eclipsed body is the pole is called the horizon of the eclipsed body. Suppose that the prime vertical, equator, and the ecliptic intersect the horizon of the eclipsed body at the points A, B and C respectively towards the east of the eclipsed body. Then the arc AB is called the *Akṣa-valana*, arc BC is called the *Ayana-valana*, and the arc AC is called *Valana*.

Valana is also called *spaṣṭa-valana*.

Valana-karma (वलनकर्म) Calculation of *valana*.

Vallakībhṛt (वल्लकीभृत्) The sign Gemini (Literally, "the lute-holder").

Vasu (वसु) Eight.

Vasundharā (वसुन्धरा) Earth.

Vahni (वह्नि) Three.

Vāra (वार) Day.

Vāruṇī (वारुणी) West.

The western direction is called *Vāruṇī* because it is presided over by *Varuṇa*.

Vāsava (वासव) The *nakṣatra* Dhaniṣṭhā, which is presided over by *Vasu*.

Vikṣipti (विक्षिप्ति) Celestial latitude.

Vikṣepa (विक्षेप) Celestial latitude.

Vikṣepa-jyā (विक्षेपज्या) The Rsine of celestial latitude.

Vikṣepa-liptikā (विक्षेपलिप्तिका) The minutes of celestial latitude.

Vikṣepāṁśa (विक्षेपांश) The degrees of celestial latitude.

Vit (वित्) Mercury.

Vidikka (विदिक्क) Contrary direction.

Vidhi (विधि) Method.

Vināḍikā (विनाडिका) A unit of time, equivalent to 24 seconds.

Vimardārdha (विमर्दार्ध) Half the duration of totality of an eclipse.

Viyat (वियत्) Zero.

Viliptā (विलिप्ता) Second of arc.

Viliptikā (विलिप्तिका) Same as *Viliptā*.

Vivara (विवर) Difference, intervening space.

Vivasvat (विवस्वत्) The Sun.

Viśākhā (विशाखा) The *nakṣatra Viśākhā*.

Viśleṣa (विश्लेष) Difference.

Viśva (विश्व) Thirteen.

Viṣuvajyā (विषुवज्या) The Rsine of the latitude (of a place).

Viṣuvaddina (विषुवद्दिन) The day of the equinox.

Viṣuvaddina-madhyāhna-cchāyā (विषुवद्दिनमध्याह्नच्छाया) The equinoctial midday shadow.

Viṣkambha (विष्कम्भ) Diameter.

Viṣkambha-dala (विष्कम्भदल) Semi-diameter, radius.

Viṣkambhārdha (विष्कम्भार्ध) Semi-diameter, radius.

Vistṛti (विस्तृति) Radius.

Vṛtta (वृत्त) (1) A circle or its cirumference. (2) Epicycle.

Veda (वेद) Four.

Vaidhṛta (वैधृत) An astronomical phenomenon. See *LBh*, ii. 29.

Vaiśva (वैश्व) The *nakṣatra* Uttarāṣāḍha, which is presided over by Viśve Devāḥ.

Vaiṣṇava (वैष्णव) The *nakṣatra* Śravaṇa, which is presided over by Viṣṇu.

Vyatīpāta (व्यतीपात) An astronomical phenomenon. See *LBh*, ii. 29.

Vyavaccheda (व्यवच्छेद) Divisor.

Vyāsa (व्यास) (1) Diameter. (2) Radius.

Vyāsa-dala (व्यासदल) Semi-diameter, radius.

Vyāsa-yojana (व्यासयोजन) Diameter in terms of *yojanas*.

Vyāsārdha (व्यासार्ध) Semi-diameter, radius.

Vyoma (व्योम) Zero.

Śakābda (शकाब्द) The years of the Śaka era.

Śakra (शक्र) Fourteen.[1]

Śakra-tārakam (शक्रतारकम्) The *nakṣatra* Jyeṣṭhā, which is presided over by Indra. (Śakra=Indra).

Śaṅku (शंकु) (1) Gnomon. (2) The Rsine of altitude (of a heavenly body).

Śaṅkvagra (शंक्वग्र) The distance of the projection of a heavenly body on the plane of the celestial horizon, from the rising-setting line of the heavenly body.

Śatabhiṣak (शतभिषक्) The *nakṣatra* Śatabhikhā.

Śani (शनि) Saturn.

Śara (शर) Five.

Śaśa-lakṣmā (शशलक्ष्मा) The Moon.

Śasāṅka (शशांक) The Moon.

Śaśi (शशि) (1) The Moon. (2) One.

Śasyucca (शश्युच्च) Moon's apogee.

Śikhi (शिखि) Three.

Śiśira-dīdhiti (शिशिरदीधिति) The Moon.

Śīghra (शीघ्र) (1) *Śīghrocca*. (2) *Śīghra* epicycle.

Śīghra-kendra (शीघ्रकेन्द्र) The *Śīghra* anomaly. See *Kendra*.

[1] There are fourteen Indras (Śakra) corresponding to the fourteen *manvantaras*.

Śīghranyāyāgatam phalam (शीघ्रन्यायागतं फलं) *Śīghraphala*. See *Śīghraphala*.

Śīghrocca (शीघ्रोच्च) See *Ucca*.

Śīghrocca-karṇa (शीघ्रोच्चकर्ण) *Śīghra-karṇa*. It is equal to $[(R \pm R \sin k)^2 + (R \sin b)^2]^{1/2}$ where $R = 3438'$, k = *koti* due to *Śīghra-kendra*, and b = *bhuja* due to *Śīghra-kendra*.

Śītāṁśu (शीतांशु) The Moon.

Śukra (शुक्र) Friday.

Śūnya (शून्य) Zero.

Śṛṅgonnati (शृङ्गोन्नति) The elevation of the Moon's horns (or cusps).

Śeṣa (शेष) Remainder, residue.

Śaila (शैल) Seven.

Saṁyukta (संयुक्त) In conjunction.

Saṁskṛta (संस्कृत) Corrected.

Sakṛt (सकृत्) By the application of the rule only once (*i.e.*, without the application of the method of successive approximations).

Saṁkhyā (संख्या) Number.

Samakala (समकल) Two planets are said to be *samakala* when they are either in conjunction or opposition in longitude.

Samapūrvāpara (समपूर्वापर) Same as *Samamaṇḍala*.

Samapūrvāparaḥ Śaṅkuḥ (समपूर्वापरः शंकुः) The Rsine of the prime vertical altitude (of the Sun)

Samamaṇḍala (सममण्डल) The prime vertical.

Samarekhā समरेखा) The meridian.

Samaliptendu (समलिप्तेन्दु) The longitude of the Moon, for the time of opposition or conjuction of the Sun and Moon.

Samparka (सम्पर्क) The sum of the diameters of two bodies in contact. Used in the sense of "the sum of the diameters of the eclipsed and eclipsing bodies."

Samparka-dala (सम्पर्कदल) Same as *Samparkārdha.*

Samparkārdha (सम्पर्कार्ध) Half the sum of the diameters of the eclipsed and eclipsing bodies.

Sahasrāṁśu (सहस्रांशु) The Sun.

Sāgara (सागर) Four.

Sāyaka (सायक) Five.

Sārpamastaka (सार्पमस्तक) Name of an astronomical phenomenon.

Sāvitra (सावित्र) Pertaining to the Sun.

Sita (सित) (1) The measure of the illuminated part of the Moon's disc; the phase of the Moon. (2) The light half of a lunar mouth (*sita-pakṣa*). (3) Venus.

Sita-pakṣa (सितपक्ष) The light half of a lunar mouth.

Sita-māna (सितमान) The measure of the illuminated part of the Moon's disc.

Surādhipa (सुराधिप) Fourteen.

Sūri (सूरि) Jupiter.

Sūrya (सूर्य) (1) The Sun. (2) Twelve.

Saumya (सौम्य) (1) North. (2) The northern (hemisphere). (3) Mercury.

Sauri (सौरि) Saturn.

Sthityardha (स्थित्यर्ध) Half the duration (of an eclipse).

Sthityardha-nāḍikā (स्थित्यर्धनाडिका) Half the duration (of an eclipse) in terms of *nāḍis.*

Sthūla (स्थूल) Gross, approximate.

Sparśa (स्पर्श) Contact.

Sphuṭa (स्फुट) True, corrected.

Sphuṭa-graha (स्फुटग्रह) True planet.

Sphuṭa-bhukti (स्फुटभुक्ति) True (daily) motion.

Sphuṭa-bhoga (स्फुट-भोग) True (daily) motion.

Sphuṭa-madhya (स्फुटमध्य) True-mean; the true-mean planet; the true-mean longitude of a planet.

Sphuṭa-yojana-karṇa (स्फुटयोजनकर्ण) The true distance (of a planet) in terms of *yojanas.*

Sphuṭa-vṛtta (स्फुटवृत्त) True or corrected epicycle.

Svadeśa-bhūmi-vṛtta (स्वदेशभूमिवृत्त) The local circumference of the Earth, *i.e.*, circumference of the local circle of latitude.

Svadeśa-bhodaya (स्वदेशभोदय) Times of rising of the signs at the local place, or oblique ascensions of the signs.

Svadeśākṣa (स्वदेशाक्ष) The latitude of the local place.

Svadeśodaya (स्वदेशोदय) Same as *Svadeśa-bhodaya.*

Svabhūvṛtta (स्वभूवृत्त) Same as *Svadeśa-bhūmi-vṛtta.*

Svara (स्वर) Seven.

Hanti (हन्ति) Occults.

Harija (हरिज) Horizon.